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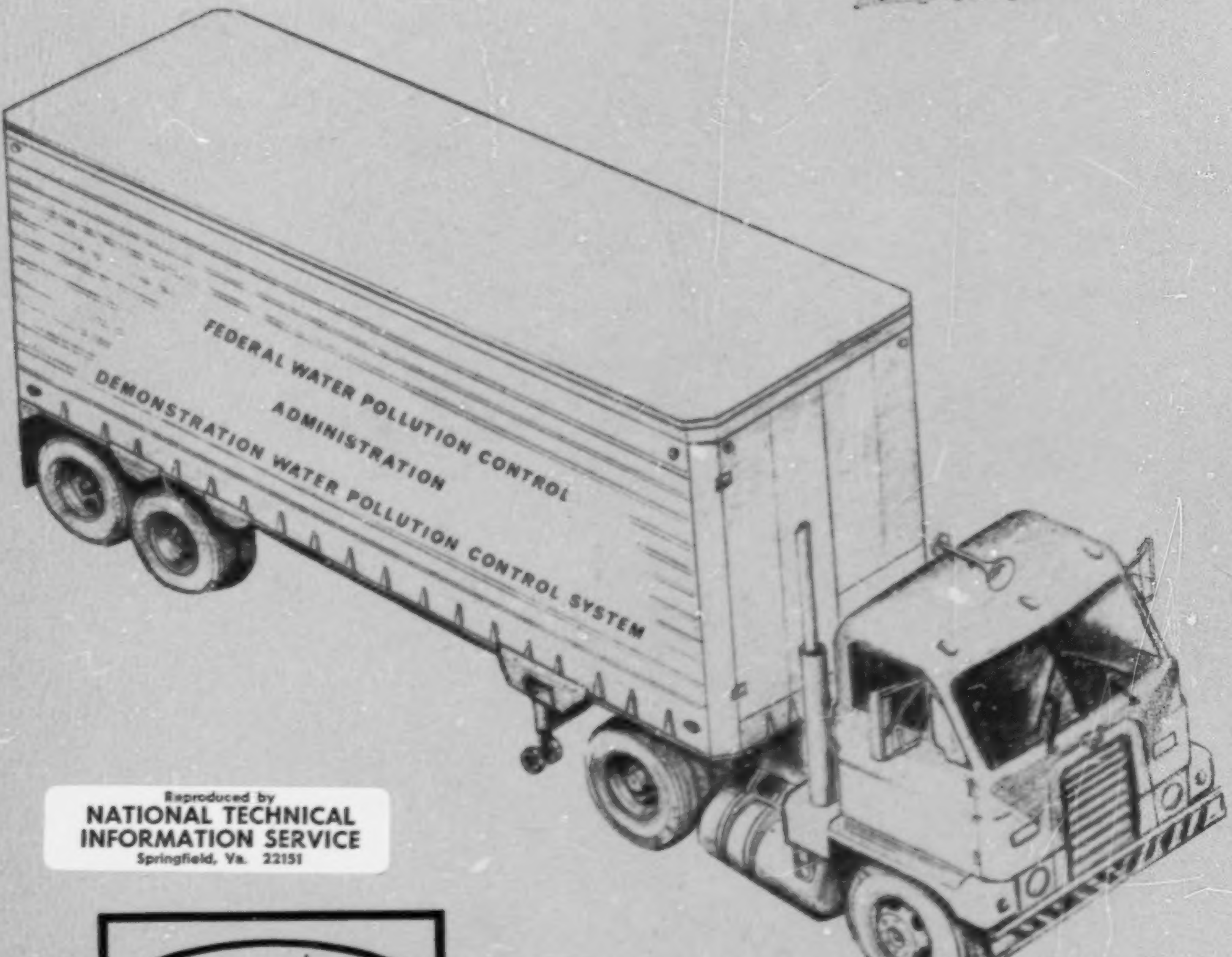
FEDERAL WATER POLLUTION CONTROL
ADMINISTRATION
DEMONSTRATION WATER POLLUTION CONTROL SYSTEM

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27 Abstract

The feasibility, both economic and technical, of using ultrasonic filtration as an aid to removing suspended impurities was investigated. Inputs to the test apparatus included drinking water, simulated sewage, primary and secondary sewage effluents, algae pond effluent, coarsely screened , raw sewage diluted 2:1, 5:1, and 10:1 with simulated storm drainage, and deliberately concentrated raw sewage. Dirt, sand, and leaves were added in some test runs with no apparent effect on performance. 20 and 50 micron filter elements, operated at approximately 10 gpm/ft^2 with head losses from 1 to 4 psi, reduced the BOD and suspended solids of raw sewage diluted in varying degrees with water by an average of 40 and 70% respectively. System performance was intermediate between that of primary and secondary treatment. Other benefits included: (1) application of ultrasonic energy increased the total quantity of effluent filtered between backwash cycles, from 4 to 18 times that treated with similar equipment without ultrasonics applied; and (2) application of ultrasonic energy restored the filter elements to "like-new" condition without necessitating frequent filter replacement. Cost figures for an ultrasonic filtration system capable of handling 1.4 mgd, exhibiting performance midway between primary and secondary treatment, and occupying only several hundred square feet, ranged between 2.8 and 3.5¢/1000 gallons. By comparison, combined primary-secondary treatment cost figures were reported as 10¢/1000 gallons excluding the cost of the considerable amount of land involved.

Abstractor Mark V. Lowry

Institution Texas Univ, Austin

5 (WRSIC abstract)

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FINAL REPORT
&
FOLLOW-ON PROPOSAL

DEMONSTRATE FEASIBILITY OF THE USE OF ULTRASONIC FILTRATION IN TREATING THE OVERFLOWS FROM COMBINED AND/OR STORM SEWERS

Contract No. 14-12-23

United States Department of the Interior

Federal Water Pollution Control Administration

Submitted By:

ACOUSTICA ASSOCIATES, INC.
5331 West 104th Street
Los Angeles, California 90045

213/OR 0-4803

September 22, 1967

TABLE OF CONTENTS

SECTION I FINAL REPORT

ABSTRACT

PART I FEASIBILITY TEST PROGRAM

I. Program Objectives
II. Personnel
III. System Description
IV. Technical Discussion
V. Test Program
VI. Test Conclusions

PART II CONCLUSIONS REGARDING THE APPROACH TO BE USED FOR A PHASED FULL-SCALE DEMONSTRATION TO EVALUATE THE SYSTEM

I. Full-Scale System Applications
II. Full-Scale Design Considerations
III. Full-Scale System Accessories
IV. Full-Scale System Installation and Operating Cost Estimates
V. Recommendations

APPENDIX A CONSULTANT'S TEST REPORT AND ANALYSIS

APPENDIX B SUMMARY OF TEST RUNS

APPENDIX C PROCEDURE FOR EVALUATING SUSPENDED SOLIDS

SECTION II FOLLOW-ON PROPOSAL

PART I PROPOSED DEMONSTRATION SYSTEM

a. General Description
b. Trailer
c. Pretreatment Screening
d. Ultrasonic Filtration System

TABLE OF CONTENTS (CONTINUED)

e. Ultrasonic Generators
f. Chlorine Treatment
g. Controls

PART II PROPOSED STATEMENT OF WORK

Program Scope

1. System Design
2. (a) Manufacturing
   (b) System Tests
   (c) Evaluation Test Program

LIST OF ILLUSTRATIONS

SECTION I FINAL REPORT

Figure No.	Title
1	Elemental Ultrasonic Filtration System
2	Photograph of Elemental System
3	35 gpm Ultrasonic Filtration Module
4	Hyperion Test Setup
5	Hyperion Test Setup
6	Test Data with City Water & 7 gpm System
7	Test Data with 50 micron Element and Sewage
8	Test Data with 20 micron Element and Sewage

SECTION II FOLLOW-ON PROPOSAL

Figure No.	Title
9-1	Proposed Mobile Demonstration System
9-2	Component Identification for Figure 9-1.

SECTION I

FINAL REPORT

ABSTRACT

The feasibility of employing ultrasonic filtration for treating overflows from combined and/or storm sewers and substantially reducing pollutant constituents such as feces, coliforms, nutrients, toxic materials and similar solid materials in suspension has been proven in a three-months test program yielding significant technical data. This new technique involves the use of permanent-type low-head filter elements which are mounted within canisters into which ultrasonic energy is applied on a programed basis. The beneficial effect of the ultrasonic energy is manifested in three significant ways:

1. During runs with ultrasonic energy applied periodically to various elements of fixed surface area, the total quantity of influent filtered between backwash cycles increased by factors of from four to 18 times that treated with similar size wire screen or porous depth-type elements operated without ultrasonic energy applied.
2. Length of filter runs between required backwashing was extended from four to ten times that hitherto obtained with ordinary permanent-type wire screen or porous elements.

3. Ultrasonic energy used during backwashing can restore the filter elements to "like-new" condition without necessitating frequent filter replacements or maintenance work of any kind.

During the three-months program, a substantial number of tests were run with drinking water, simulated sewage, primary and secondary sewage effluents, influent from algae ponds, coarsely screened raw sewage, raw sewage diluted 2/1, 5/1 and 10/1 with simulated storm drainage, and deliberately concentrated raw sewage. Dirt, sand and leaves were also added in some test runs with no apparent effect on performance. Reductions in BOD and suspended solids averaging between 40% and 70% were obtained in a selected number of tests with raw sewage diluted in varying degree with water using 20 and 50 micron elements at filtration rates approximating 10 gpm/sq ft and at a head loss of from 1 to 4 psi. System performance was consistently better than primary treatment, probably intermediate between primary and secondary treatment.

Based upon the tests conducted with simulated "combined" sewage, it is concluded that the ultrasonic filtration system is technically and economically feasible for full-scale waste water treatment use. A cost analysis for an overflow treatment system requiring only 100 sq ft of installation area and having a capacity of 1.4 mgd is presented in this report. This same type of system for either mobile or static installations may also be employed in a number of other waste water and fresh water treatment applications using filter elements as fine as 1 micron.

PART I

FEASIBILITY TEST PROGRAM

I. PROGRAM OBJECTIVES

In support of the requirements of the contract listed in the Statement of Work, the contractor established the following program objectives to facilitate proper performance of its effort:

a. Determine performance of the ultrasonic filtration mechanism in a small filtration system capable of handling a maximum flow of approximately 7 gpm and collect operating data using simulated "combined" sewage containing suspended debris comprised of organic and inorganic particles.

b. Compare the results obtained with the 7 gpm system with a larger system having a flow capability of 35 gpm.

c. Obtain performance data by operating the 7 gpm system with the influent from an operating sewage treatment plant utilizing primary and oxidation pond treatment. Tests involving treated sewage exceeded the requirements of the contract but were believed to be most desirable in verifying the expected performance of ultrasonic waste water treatment.

Early in August, following discussions held between the FWPCA and the contractor, the program objectives were modified to place greater attention on tests using coarser filtration elements than the 1 and 2 micron elements that had been used initially. The contractor also directed its attention to tests using raw sewage, since simulated materials proved to be of questionable value in determining system feasibility. Tests were also run at the suggestion of the Project Officer using undiluted raw sewage containing additional amounts of deliberately added sludge.

II. PERSONNEL

During the month commencing on August 12, 1967, the following key contractor personnel were directly involved in this program:

Robert L. Rod	President
Frank DeLuca	Executive Vice President
Arthur Fontana	Program Manager
Conrad Bodai, Ph. D.	Chief Scientist
Walter Penick	Project Engineer
John Bennett	Reliability Engineer
Robert Bohannon	Technician
Charles L. Senn, P. E., M. S.	Consultant in Civil and Sanitary Engineering and Professor of Public Health, UCLA
Donald R. Gooden, R. S.	Consultant in Sanitation
Glenn Smith	Outside Analytical Services
Pomeroy, Johnston & Bailey	Outside Analytical Services

III. SYSTEM DESCRIPTION

The ultrasonic filtration system investigated for feasibility in waste water applications is shown in elemental schematic form in Figure 1 and in the photograph of Figure 2, which illustrates a dual 7 gpm filtration system employed during this program for a number of the aforementioned tests. The dual system contains two identical filter canisters, each measuring 12" x 6" OD, which were used alternatively to maintain flow on an almost continuous basis. While one filter is maintaining normal flow, the other is quickly backwashed and made available for further forward flow. Each canister is fabricated from stainless steel throughout, except for gasketing of neoprene, and is fitted with solenoid valves permitting the various functions to be programed automatically from a control box. Complete instrumentation includes gages for making inlet pressure measurements

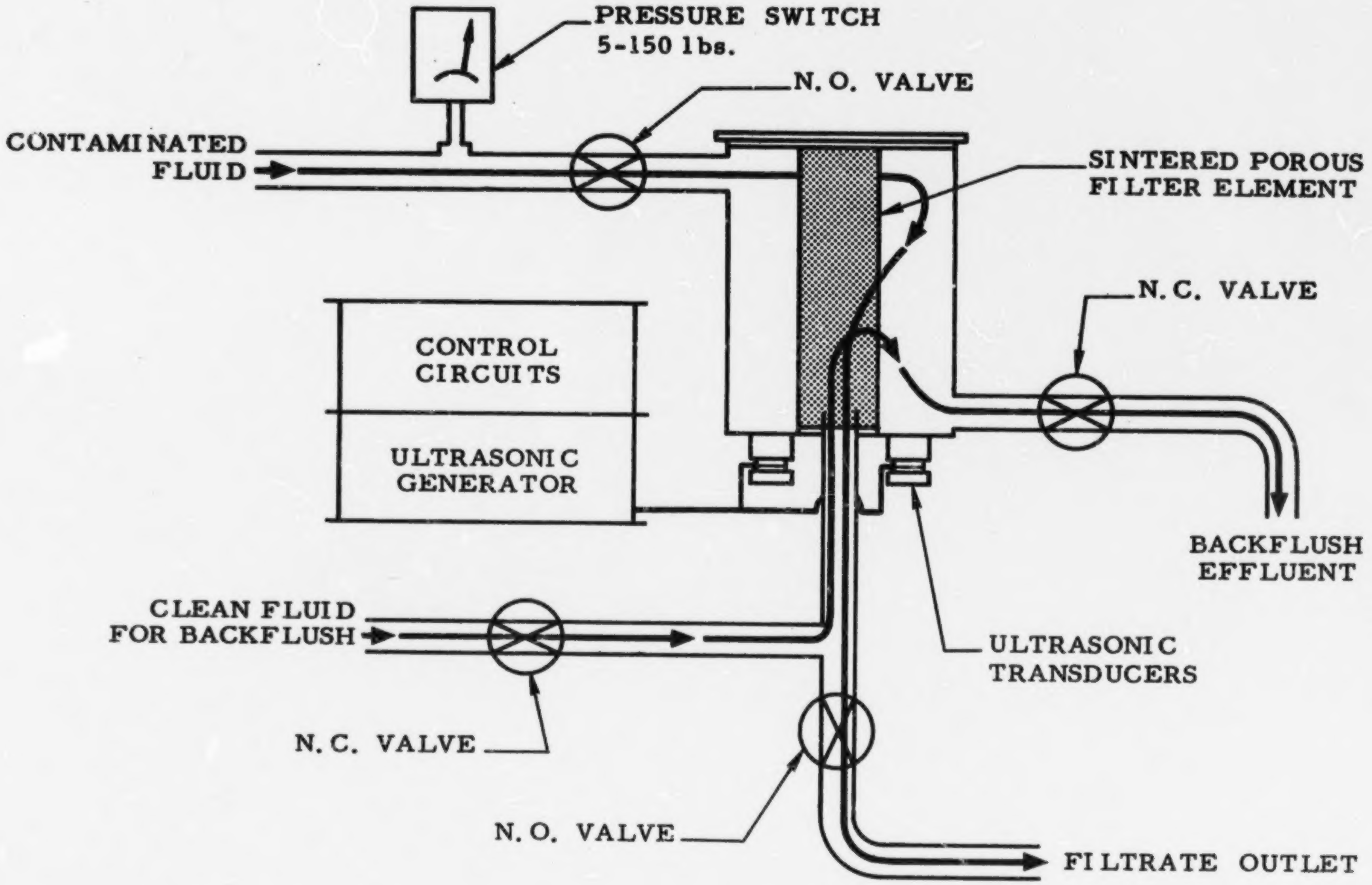
PRESSURE SWITCH
5-150 lbs.
N.O. VALVE
CONTAMINATED
FLUID
SINTERED POROUS
FILTER ELEMENT
N.C. VALVE
CONTROL
CIRCUITS
ULTRASONIC
GENERATOR
BACKFLUSH
EFFLUENT
CLEAN FLUID
FOR BACKFLUSH
ULTRASONIC
TRANSDUCERS
N.C. VALVE
N.O. VALVE
FILTRATE OUTLET

Fig. I
ULTRASONIC FILTER UNIT

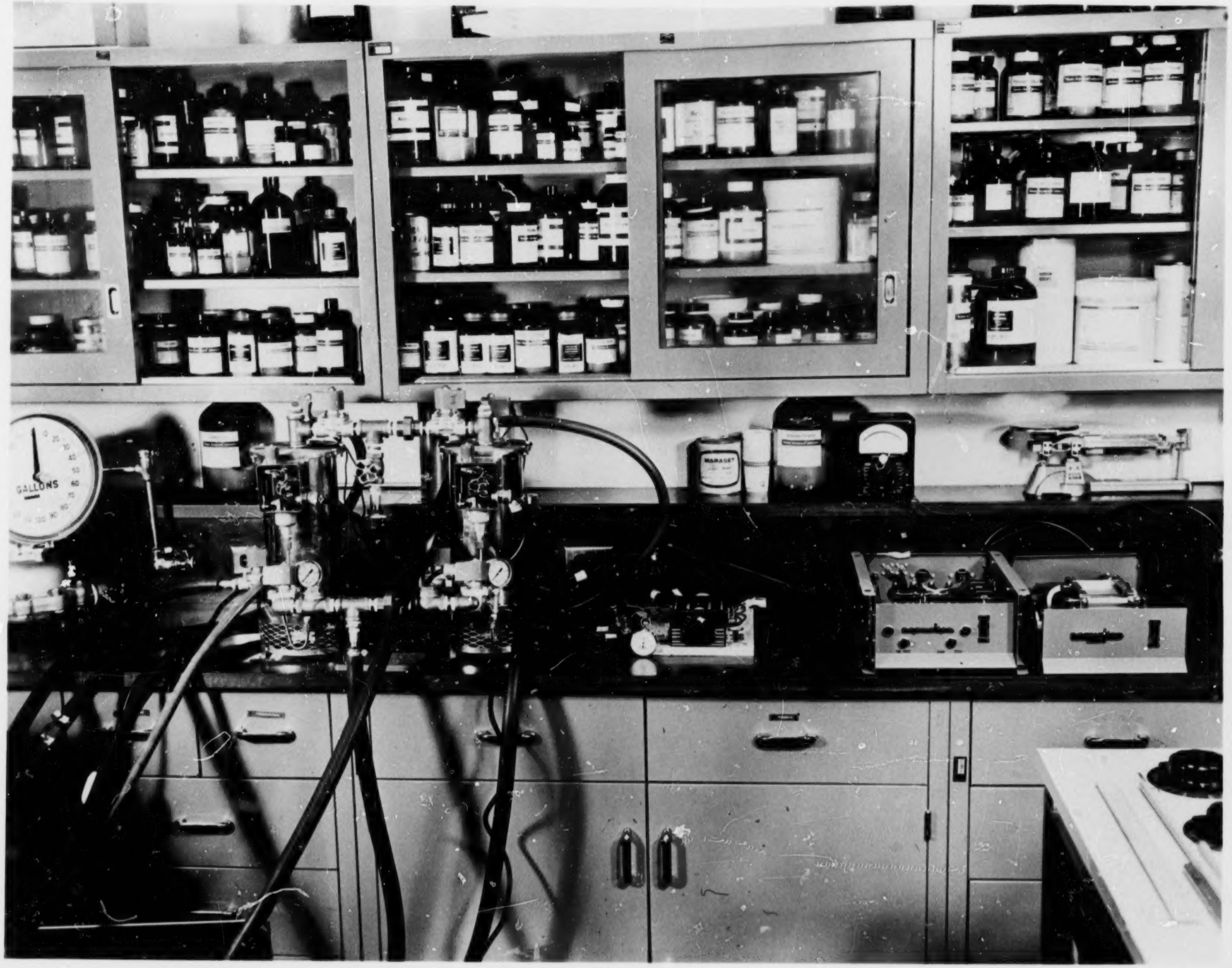

FIG. 2

across the filter elements and an accurate flow meter indicating the exact quantity of filtered effluent.

In operation, influent passes through the filter element(s) in a normal manner. From time to time one-second long bursts of ultrasonic energy are applied to transducers mounted on the underside of the filter canister while normal flow is being maintained. The onset of this ultrasonic pulse is accompanied by a simultaneous closing of the outlet valve and an opening of the so-called, "spritz" valve to remove debris adhering to the surface of the filter element and force it into the water-filled volume surrounding the element.

When the spritz is completed, the pressure drop across the element, which gradually increases as the filter becomes more contaminated, drops abruptly to a lower value. It has been found that a small proportion of entrapped particles of soft consistency break down into smaller particles during the ultrasonic spritz action and pass through the filter unimpeded. Others appear to agglomerate and fall to the bottom of the canister by gravity where they are removed in some degree during spritzing or completely during subsequent backwashing operations. Thus, the greater majority of suspended particles of solid or elastic nature, such as sand, metal, cloth, feces, paper and minerals, to name but a few, that cannot pass through the pores of the filter are trapped for subsequent recovery.

Since the so-called, "soil holding capacity" of the filter media is finite, the system eventually builds up sufficient debris within the canister to require removal by backwashing. This condition is programed by sensing the pressure buildup across the filter, or, alternatively, by selecting a set time period between backwashing cycles. This backwashing action restores the filter media to its original condition of cleanliness, and oftentimes to a cleanliness level exceeding that of "new" elements obtained from their manufacturer. The total amount of water lost during a complete backwashing cycle varied between 0.5 and 3.5% of total flow depending upon the level of influent contaminants and the degree of pretreatment.

In numerical terms, the cylindrical filter element used in the small equipment shown in Figure 2 had an outer diameter of 2.75 inches and a length of 10 inches approximating 0.6 sq ft of effective filtration area. As may be expected, there was a direct relationship between the filtration rate in gpm per sq ft and head loss. Tests were performed in two ways. One was to maintain constant flow rate as with a rate-of-flow controller. The other was to have a high initial flow rate which gradually diminished as the head loss increased. Later in the program, smaller diameter elements measuring 1.75 inches in diameter and having effective lengths of 6-1/2, 16-1/2, and 33 inches were used. These elements exhibited filtration rates comparable to the larger diameter element and enabled the contractor to compare performance and costs for canisters of differing geometry.

The contractor also conducted tests of a larger canister, Figure 3, capable of handling over 30 gpm flow. This unit, which was tested on runs

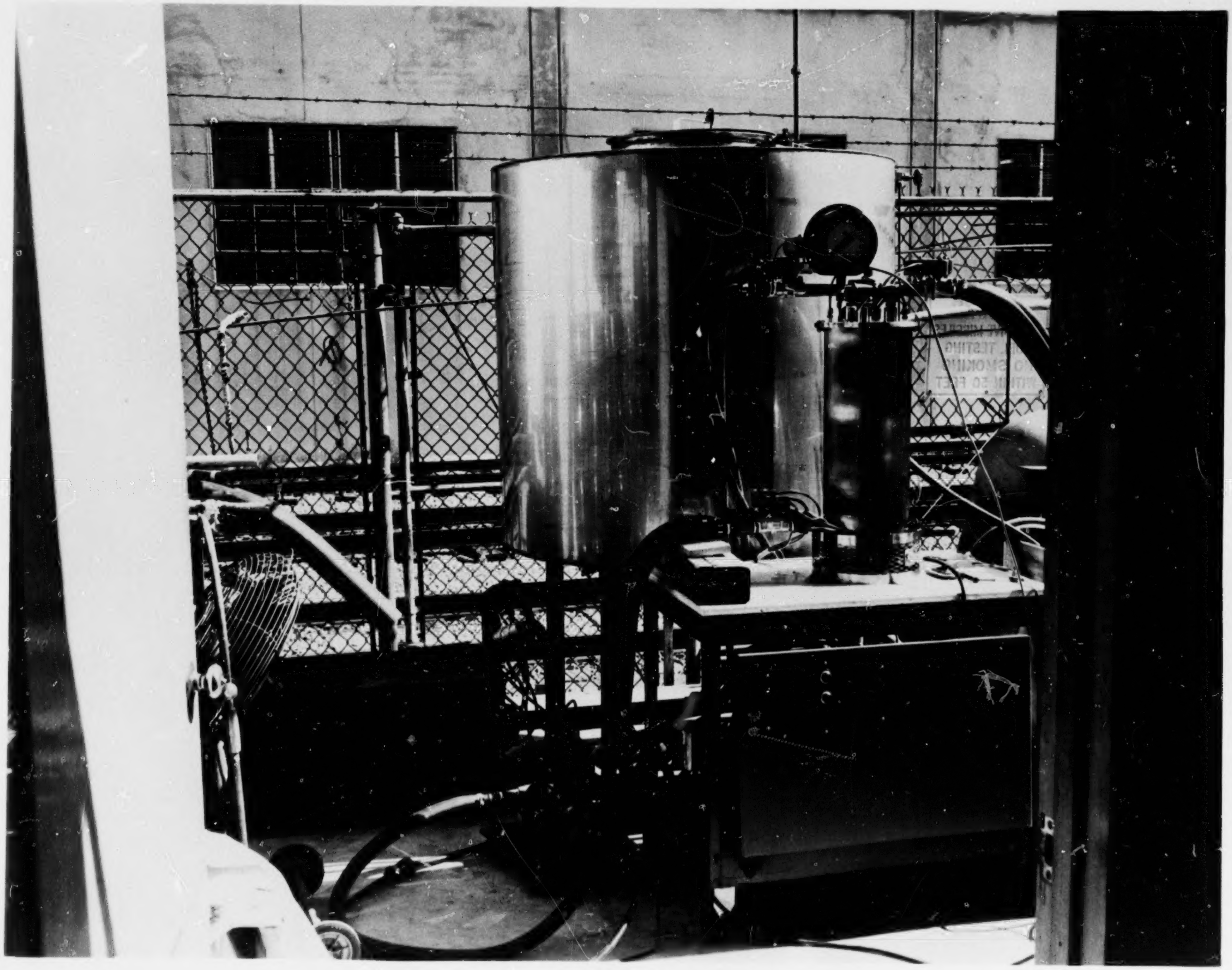
TESTING
SMOKING
WITHIN 50 FEET

FIG. 3

with city water and 1 micron elements, consisted of three separate 20 inch long cylindrical elements, each having a diameter of 2.75 inches, which were mounted within the common canister. Long test runs using this three-element system were found to be impractical under laboratory conditions due to the extensive water storage and pumping facilities required. Subsequent investigations later determined the advantages of using single element configurations centrally located within the canisters which provide a more highly concentrated ultrasonic field at the surface of the filter elements. This additional energy lengthens flow runs and improves upon the backwashing, especially with highly contaminated influents such as sewage.

IV. TECHNICAL DISCUSSION

During the three-months feasibility study, the contractor conducted the program in close conformity with all of the aforementioned program objectives. Initially, a literature search was undertaken to determine the magnitude of suspended solids and BOD that could be expected in treating the overflows from combined and/or storm drains. Parallel work was undertaken to devise suitable simulated sewage materials that could be used in the feasibility runs.

The first of the feasibility test runs was made using Los Angeles City water as available in the contractor's plant which analysis of several samples proved to contain up to 119 mg/l of suspended solids, the greater portion being collected on Millipore plates consisting of particles under 10 microns in size. Additional solids were present in the 10 - 20 micron size range with somewhat lesser amounts in the 20 - 40 micron size range. In each sample examined, a number of different common aquatic organisms were observed both with the naked eye and in greater detail under a microscope. Since the greatest proportion of solids by weight appeared to be under 10 microns in diameter, system feasibility was first determined with filter elements having a 1 micron nominal, 11 micron absolute rating. Test data, which are summarized in the following section, determined that the flow rate using city water and a 0.6 sq ft 1 micron element in a canister without ultrasonic energy applied dropped from a maximum of 7 gpm to 3 gpm in 3 minutes and clogged to zero in less than ten minutes.

The same test was repeated with ultrasonic energy being applied in the proper sequence for 35 minutes during which time the flow dropped from the maximum value to an arbitrarily selected end-point of 70% of maximum flow. Reduction of suspended solids in the drinking water averaged 54% in this test. Total flow during three successive 35 minute runs with a 1 micron element averaged 180 gallons, with an average flow of 5 gpm and an average rate of over 8 gpm/sq ft of filter surface area. The length of the run with ultrasound thus exceeded the run without ultrasonics by tenfold, while the amount of backwash water required dropped by a factor of ten. Since approximately 3 gallons were needed for backwashing, the percentage of backwash water required for the ultrasonic run was 3/180 or 1.7%.

Immediately upon the conclusion of the in-plant runs with city water, the contractor undertook a series of tests of 1 and 20 micron sized filter elements with undiluted influents of primary and secondary sewage treatment units conducted on-site at the Lancaster, California, facility of the Los Angeles County Sanitation Districts. As expected, these extremely fine pored elements clogged up in a matter of minutes on both influents without pretreatment, the latter containing a high concentration of algae which developed in the oxidation pond used for secondary treatment. Nevertheless, in one brief five minute test of a 10 micron element, the algae in the influent was reduced by the ultrasonic filter from a count of 450,000 per ml to 6,000 per ml. This superior performance can be compared to that obtained with a two step experimental system nearby using coagulation with alum floc treatment followed by conventional filtration, which yielded a final effluent algae level of 10,000 per ml. The concentration of algae in the backflush of the ultrasonic filter exceeded several million per ml.

Before leaving the Lancaster facility to undertake tests with raw sewage and coarser filtration elements at the more convenient Hyperion Treatment Plant of the City of Los Angeles, three ultrasonic filtration tests using coagulation for pretreatment were conducted. The effluents from the primary treatment unit and two batches obtained from the oxidation ponds at Lancaster, which were heavily loaded with algae, were flocculated in a 55 gallon drum with ferric chloride in the ratio of 250 ppm* and allowed to settle for 30 minutes. When the pretreated primary effluent was run through the 1 micron ultrasonic filter unit, it ran 10 minutes and delivered all 46 gallons available in the batch. During this period the pressure across the system increased from 10.5 to 19 psi and, as might be predicted, a run using primary effluent with the 20 micron element exhibited an increase of pressure from 8.0 to 8.5 psi during an entire 45 gallon run. Unfortunately, tests with secondary influent containing the algae in large amounts were not conducted because ferric chloride appears unable to flocculate this type of influent. However, these tests of a 0.6 sq ft area element indicated that coagulation techniques used in conjunction with the ultrasonic filter and optimized flocculants** should have certain practical applications involving both the harvesting of algae and for difficult waste water treatments that appear worthy of further study.

These aforementioned tests with 1 and 20 micron elements were considered to be most useful in determining the utility of the ultrasonic filtration technique for polishing water and for tertiary sewage treatment and clearly indicate performance exceeding that of competitive filtration systems. For treatment of overflows from combined and/or storm sewers, however, it became evident that coarser filtration elements could be used to advantage with the attending benefits of greater flow, reduced head losses, and longer runs. Thus, midway in the program, it was decided that the major effort would thereafter involve runs using 20 and 50 micron elements handling actual raw sewage influents including a number in which the raw sewage was diluted in varying degrees to simulate combined sewage.

---

* Dosage required was determined experimentally in the field with no attempt at optimization or pH adjustment.

** The contractor understands flocculants for algae are under development by North American Aviation, Inc.

The most significant tests directly relating to the treatment of overflows from combined and/or storm sewers were conducted at the Hyperion Treatment Plant within a few miles of the contractor's facility. Through the excellent cooperation of municipal authorities and the plant supervisory staff, every needed facility was placed at the disposal of this contractor by a resolution adopted by the Board of Public Works Commissioners of the City of Los Angeles. Figures 4 and 5 illustrate views of the selected test area located inside the "Headworks Building". Sewage arriving at the building, which handles some 450 mgd flow, is first passed through coarse bar screens and a detritor, which provided the sewage used in these feasibility tests.

During August and early September, a series of runs were made with raw sewage diluted 2/1, 5/1 and 10/1 with city water applied to three different ultrasonic filtration module configurations. Since large pieces

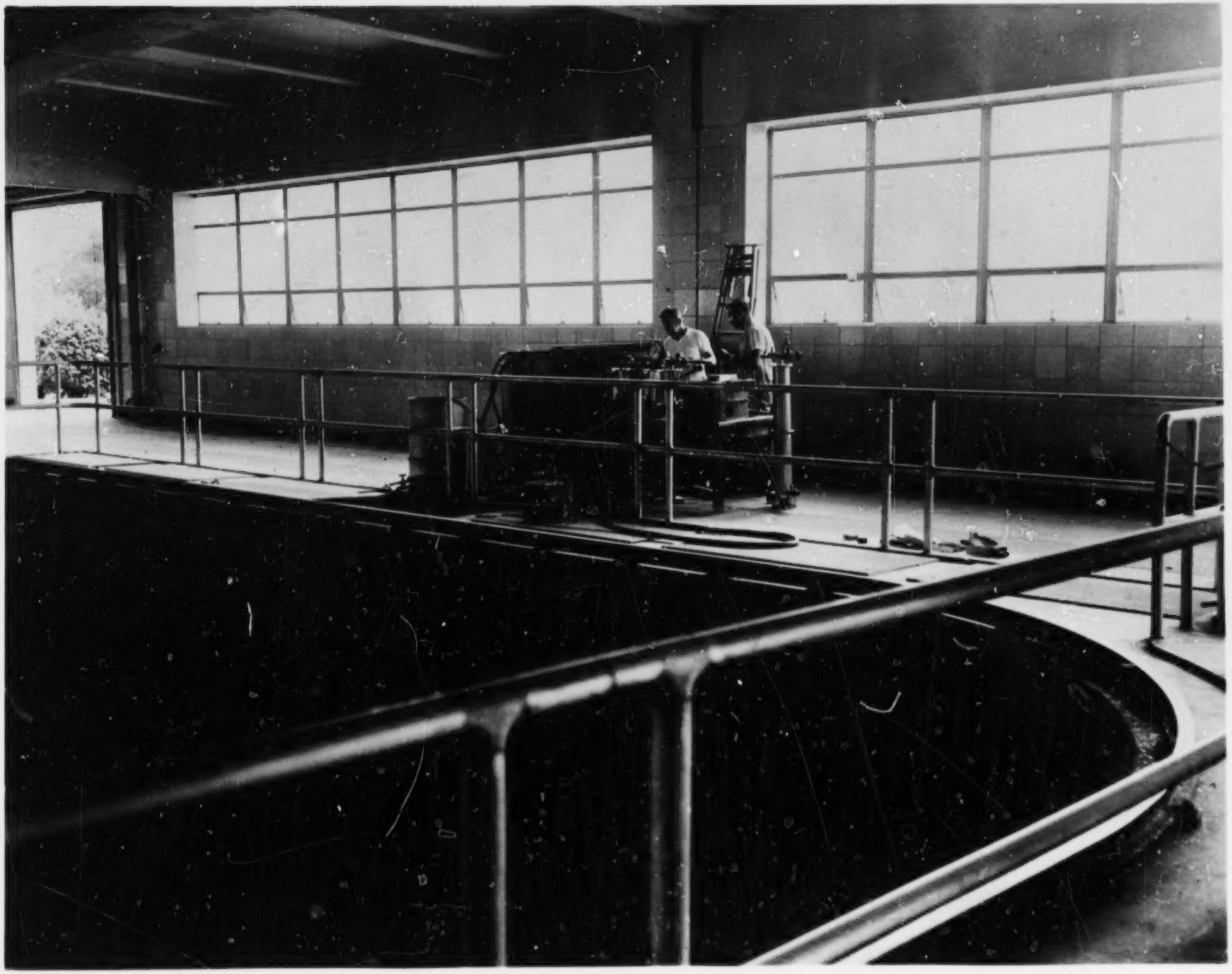

FIG. 4

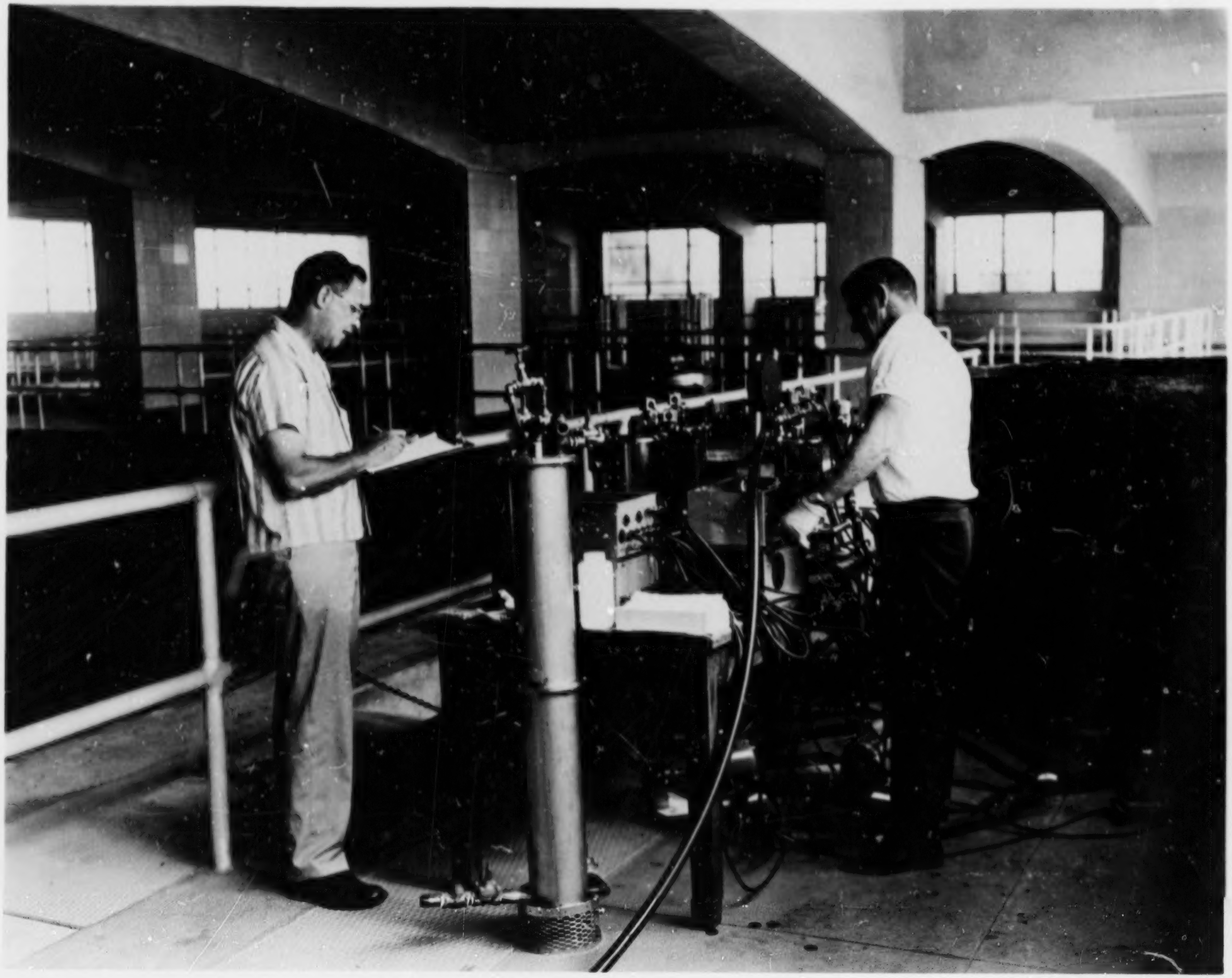

FIG. 5

of paper and other materials might adhere to the filter element and not be dislodged, all the sewage in the tests was first passed through a 14 mesh* bronze screen strainer to remove such debris before it was pumped into a 600 gallon storage tank used both for mixing and the source of influent to the filter. Very little material was captured by this strainer, as evidenced by frequent examination, and thus the various performance figures cited in the following test data section and in the appended report of Acoustica's Consultant in Civil and Sanitary Engineering represent almost entirely the performance of the ultrasonic filtration system and not the pretreatment and screening. During each run, the mixture of raw sewage and simulated rainwater (plus in some test runs with sand, soil and leaves added) was kept in agitation by constant paddling to maintain particulates in suspension.

Three sets of laboratory measurements of BOD, suspended solids, as well as coliform reduction were made on samples collected in a representative number of test runs by an outstanding independent firm of sanitary engineers. Test runs conducted for the purpose of determining these parameters with various levels of dilution were made with 50 micron elements with significant results in terms of BOD reduction and suspended solids removal. Another run was made with a two step process using 50 and 20 micron elements. The runs, which were performed using the normal automatic ultrasonic sequencing, were each followed by a manually activated backwashing operation using ultrasonics which restored the filter element to a clean condition. Separate runs without ultrasonic energy also were made to ascertain the improvement in forward flow afforded by the ultrasonic technique, and therefore no measurements of BOD, suspended solids and coliform were deemed necessary in that mode of operation.

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* 14 mesh obtained from 0.020 inch dia. wire woven on a rectangular grid with center-to-center spacings of 0.051 inch yielding an open area of 51% that will retain particles larger than 1,200 microns in diameter.

Lastly, at the suggestion of the FWPCA Project Engineer, several test runs involving laboratory tests were made in which undiluted raw sewage was applied directly to 50 micron elements. These tests were repeated using the same raw sewage influents to which additional sludge was added deliberately to increase the normal BOD and suspended solids loading encountered in raw sewage.

V. TEST PROGRAM

Tests conducted during the three-months program which are itemized in Appendix B essentially fall into two main groups. The first group of tests primarily centered about the use of the 7 gpm unit with the 0.6 sq ft 1 micron nominal, 11 micron absolute filter element handling an influent of city water, while the second group involved test runs using coarser elements of 50 and 20 micron size and 0.6 sq ft area handling influents of raw sewage.

In between these two major test groups were runs made at Lancaster using 1 and 20 micron elements in similar equipment with sewage influents. Since the finer pore elements clogged in a matter of gallons when handling sewage primarily due to the colloidal nature of such material, significant data were collected only during runs with influents that were pretreated by flocculation. In these tests, excellent hydraulic parameters similar to those noted with city water were obtained. Unfortunately, BOD determinations made at Lancaster were not properly performed and had to be discarded.

All significant tests throughout the entire program included the preparation of Millipore filter discs which were examined microscopically in the laboratory. Matching samples of filter influent and effluent were subjected to a determination of suspended solids and a particle size count for solids above 10 microns in diameter.

a. GROUP A - Tests with City Water and Micron-Sized Elements

Figure 6 is a graph showing the performance of the 7 gpm system operating with an influent of Los Angeles city water. Three different sets of data are included in this graph depicting performance obtained with a filter element having the aforementioned 1/11 micron-sized pores and a surface area of 0.6 sq ft. The first significant data produced a "control" curve showing that this particular filter element without ultrasonic activation completely clogged up on city water in less than ten minutes. Actually, a flow rate of 7 gpm in a thoroughly cleaned element dropped to about 3 gpm in three minutes.

As opposed to the poor results experienced with an ordinary filter element without ultrasonics, the tests run with the full ultrasonic cycling showed that the same filter element was capable of operating virtually indefinitely at optimum flow. The curve of these data shows the relationship between flow and time for a single element subjected to a one second spritz every ten seconds. As will be noted, flow lessened from maximum to about 70% of maximum over the arbitrary time period between backflushing of 35 minutes, although the average flow maintained during the period was well over the 70% point. During the three successive runs, it was noted that the flow gradually increased from that first obtained with a supposedly clean element by a small but significant amount, a situation explained by the effectiveness of the over-all ultrasonic cleaning operation.

The upper curve on the graph shows total flow in each run between backflushing. The total flow of 177 gallons achieved during the first run increased to at least 180 gallons in successive operating cycles and varied slightly as the quality of the influent changed from time to time. The average flow after conditions optimized was 5 gpm or over 8 gpm/sq ft of filter area.

These data were further refined by making a detailed analysis of the solid entrapment capabilities of the ultrasonic filtration system in terms of both weight and particle sizes, as shown in the following tables. In each case, three measurements were made at different times during one 35 minute run of the raw water influent, the filtrate effluent and the spritz. One measurement was made of the following backflush effluent. These data are now summarized:

WEIGHT ANALYSIS*

SAMPLE NO.	SOLIDS, mg/l
1A Raw Water	111
1B Raw Water	115
1C Raw Water	119
2A Filtered Water	55
2B Filtered Water	54
2C Filtered Water	57
3A Spritz	56
3B Spritz	58
3C Spritz	36
4C Backflush	131**

**This figure is believed deceptively low by as much as a factor of ten and results from sampling the non-settled portion of the backflush over a short time period. Improved measuring techniques will be used to further clarify the clearly evident discrepancy between soil trapped in the filter and that actually collected.

RELATIVE NUMBER OF PARTICLES ABOVE 10 MICRONS PASSING THROUGH FILTER, BY PARTICLE SIZE

Sample No.	10 - 20 Microns	20 - 40 Microns	40 - 60 Microns	Over 60 Microns	Comment
1A	2310	308	0 0	0	Influent
1B	1973	285	7	2	Influent
1C	3020	385	16	0	Influent

* Tests performed in accordance with Acoustica Document DO 6024, pp 31-38, attached as Appendix C which conform to those defined in STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTE WATER, 12th Ed., APHA, AWWA, WPCF, pp 244-248.

Sample No.	10 - 20 Microns	20 - 40 Microns	40 - 60 Microns	Over 60 Microns	Comment
2A	925	11	0	0	
2B	770	9	0	0	
2C	616	5	0	0	Quantity increased on particles under 10 microns.
3A	942	3	1	0	
3B	910	4	0	0	
3C	870	1	0	0	
4C	3123	1120	96	13	

The above data conclusively show that over 50% of the suspended solids in Los Angeles city water by weight were removed by a 1/11 micron element and that 97% of the particles larger than 20 microns were also removed.

b. GROUP B - Tests with Raw Sewage and 20 and 50 Micron Elements

This section summarizes hydraulic test parameters obtained in a large number of different runs with sewage at the Hyperion plant. Analysis of laboratory test results for three representative runs in terms of BOD, suspended solids and coliform reductions are given in the appended report prepared by Acoustica's Consultant in Civil and Sanitary Engineering.

Figure 7 illustrates hydraulic filter performance curves similar to Figure 6 which were obtained from successive tests of a 50 micron element filtering raw sewage diluted 10:1, 5:1 and 2:1 with city water. Three of the curves show performance of the filter without ultrasonic energy applied both in terms of flow rate and total flow obtained until the head loss across the filter and a solenoid valve in series increased from the low

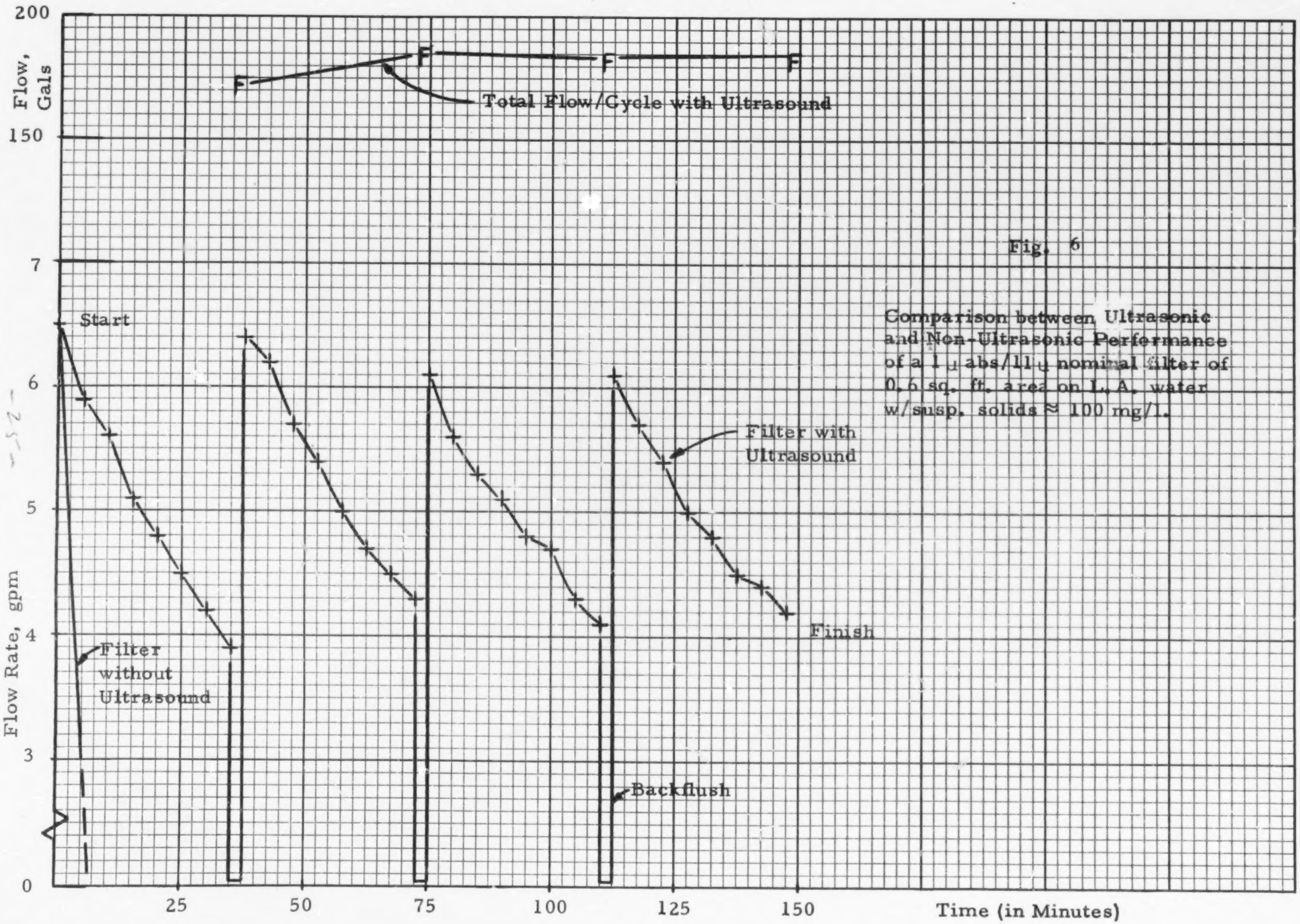

Fig. 6

Comparison between Ultrasonic and Non-Ultrasonic Performance of a 1 μ abs/11 μ nominal filter of 0.6 sq. ft. area on L.A. water w/susp. solids ≈ 100 mg/l.

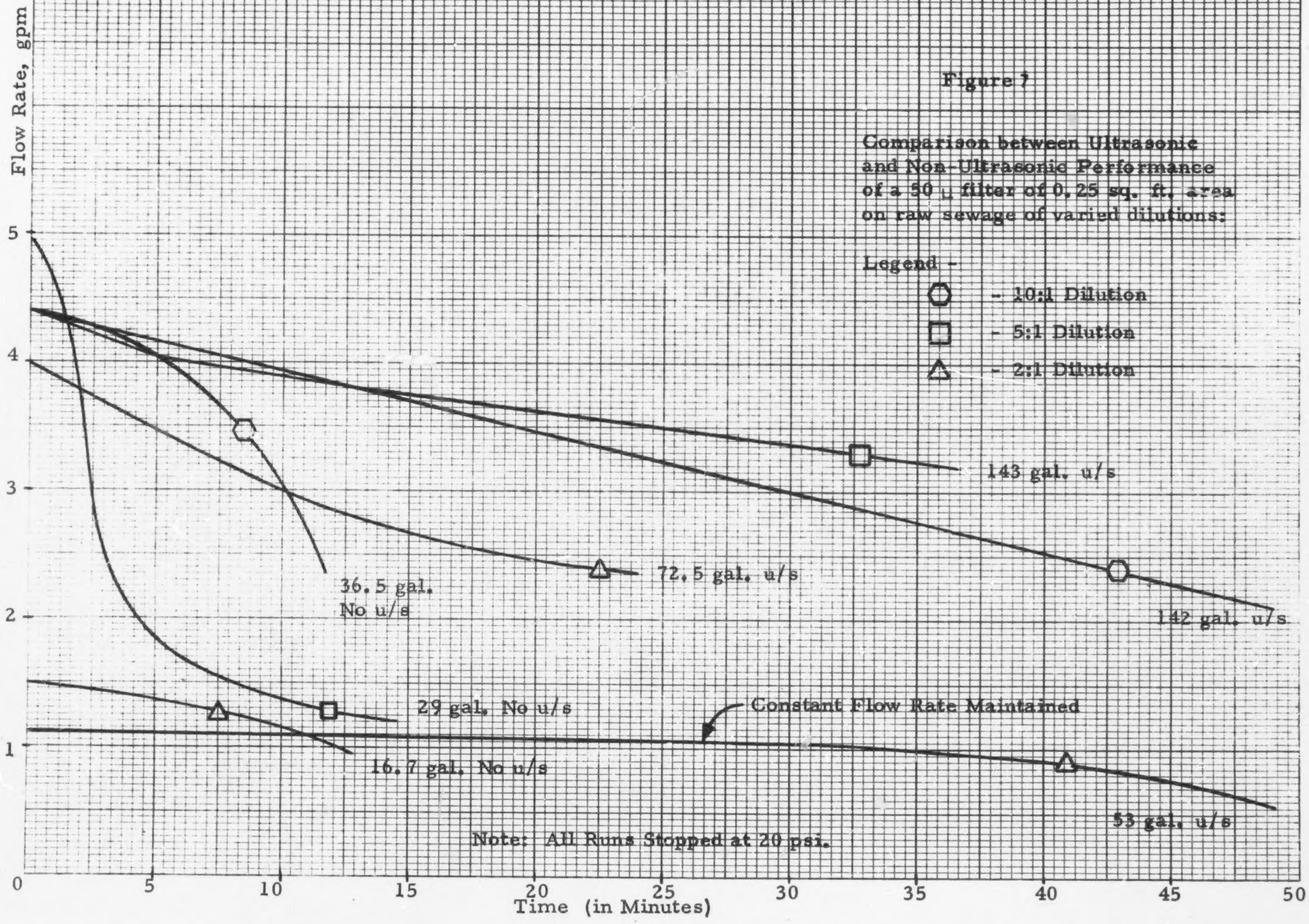

Figure 7

Comparison between Ultrasonic and Non-Ultrasonic Performance of a 50 μ filter of 0.25 sq. ft. area on raw sewage of varied dilutions:

Legend -
- ⬡ - 10:1 Dilution
- □ - 5:1 Dilution
- △ - 2:1 Dilution

Note: All Runs Stopped at 20 psi.

initial value of 2 to 3 psi to an arbitrary limit of 20 psi. The four other curves, including one run operated at a constant flow rate of 1.1 gpm, show the improved results with ultrasonic energy applied.

It can be seen from these curves that a four-fold improvement in total flow was achieved between runs with ultrasonic energy and those without. As expected, total flow achieved before backwashing was required increased with the dilution ratio and approximately doubled between dilution ratios of 10:1 and 2:1. All of these data represent runs made with one particular 50 micron filter element measuring 1.75 inches in diameter and 6.5 inches in length, or 0.25 sq ft of surface area.

Figure 8 depicts the results of raw sewage tests made with two different size 20 micron elements in three different ultrasonic runs of particular interest. One run was made with an elongated element measuring 16.5 inches in effective length and 1.75 inches in diameter, or 0.6 sq ft of surface area. The average flow rate between the initial 7.8 gpm value at the start and the 4.1 gpm value at the end-point wherein total system pressure drop increased from 4 to 20 psi was 5.8 gpm. This is equivalent to a filtration rate of 10 gpm/sq ft when handling a dilution ratio of 10:1. The second element twice as long as the first having a surface area of 1.2 sq ft produced an average flow of 6.8 gpm and a filtration rate of 5.7 gpm/sq ft under similar conditions with sewage diluted 10:1.

The decrease in flow rate between elements differing twice in area was partially the result of maintaining the ultrasonic generator power the same in both runs and thereby penalizing the performance of the longer element. However, some additional performance loss, which can be avoided in the future, was contributed in the higher flow tests by pressure restrictions in the under-sized solenoid valves used. These valves were uniformly of 3/4 inch size in all Hyperion runs, a size that is best suited for a nominal 5 gpm flow. Bigger valves could have been used to advantage, particularly in tests of larger elements, since they will lower the pressure developing across a filter element and thereby decrease the possibility of driving soil particles deep in the pores of the filter, but they were unavailable in the time allowed for the test program. When properly sized valves are used, the head loss across the filtration system should drop in half, while the efficiency of the filter should improve in terms of length of run and flow rate.

The third curve on Figure 8 illustrates the performance of the 20 micron element when handling an influent previously filtered through the 50 micron ultrasonic filter. The influent of raw sewage to the 50 micron element was diluted 2: 1 with city water. The flow rate of 5 gpm was maintained practically without degradation until all 50 gallons of available influent were used. There was no sign of clogging indicating that this type of pretreatment may be desirable in certain practical applications.

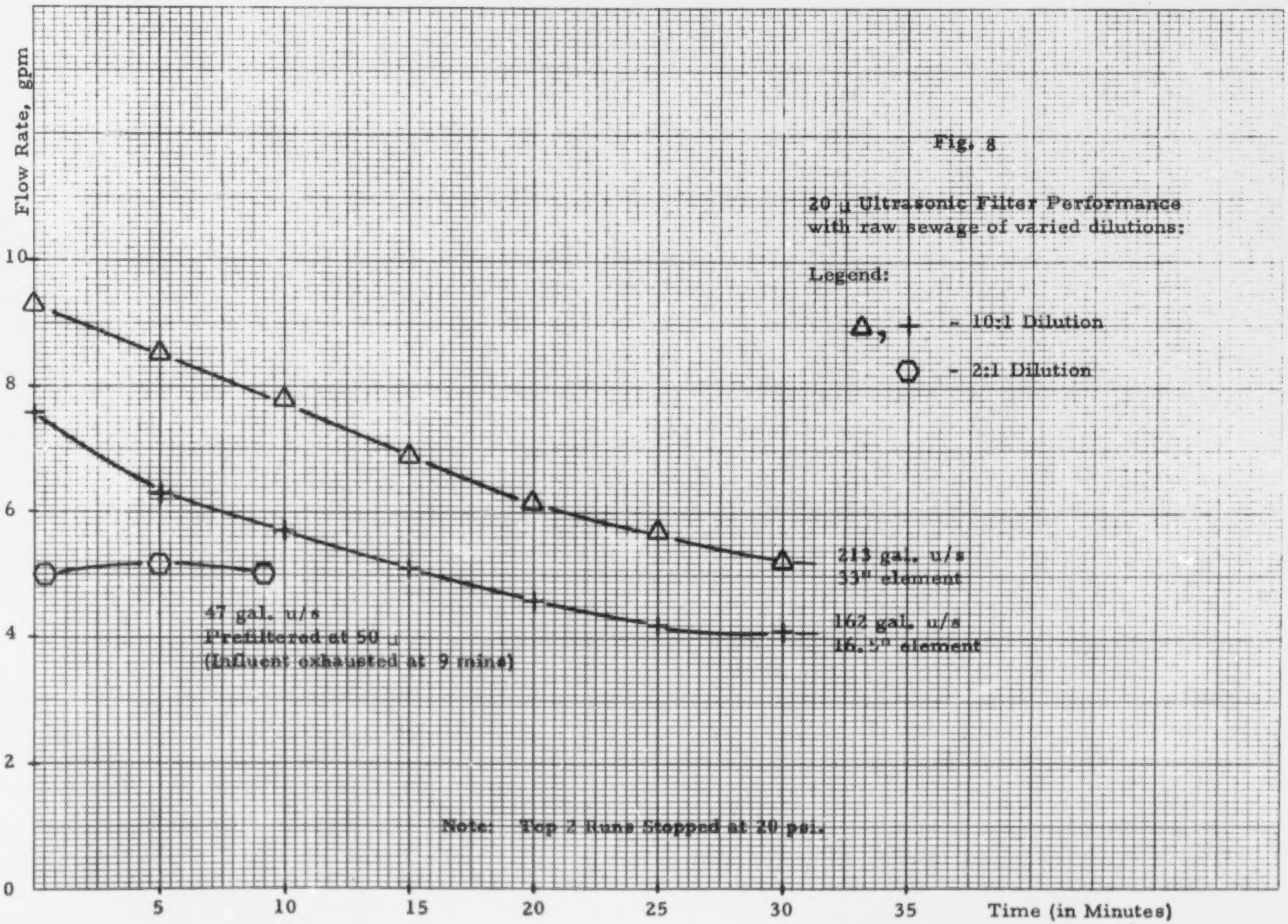

Fig. 8

20 μ Ultrasonic Filter Performance with raw sewage of varied dilutions:

VI. TEST CONCLUSIONS

The major conclusions reached as a result of the test program are several in number and are itemized as follows:

a. Ultrasonic filtration is a feasible technique for removing suspended solid materials from a variety of contaminated influents. As compared to the performance of conventional permanent-type filter elements, the ultrasonic system exhibits marked increases in the length of flow runs and in the average flow rates between backwashing cycles. Typical flow rates that were achieved in a large number of runs using a wide variety of influents consistently averaged 10 gpm/sq ft.

b. The optimized basic building block configuration is a single cylindrical canister module measuring 6 inches in outer diameter and 20 inches high which contains a centrally located permanent-type element measuring 1.75 inches in diameter and approximately 20 inches in length. This canister which will filter between 5 and 10 gpm, depending upon the pore size selected, is energized with a 350 watt output ultrasonic generator one second every ten seconds during forward flow and again on a continuous basis during backwashing. Groups of modules are used in parallel to accommodate greater flows.

c. Depending upon the nature of a particular influent, useful pore sizes range from 1 to over 50 microns. In using the 1 micron element without pretreatment, for example in water polishing, the influent desirably should be free of fine colloidal materials to achieve economical performance. In combination with an appropriate flocculation pretreatment, it appears feasible to use 1 micron filter elements with a variety of influents heavily loaded with colloidal materials, including primary effluents and others rich in algae. The 50 micron element with minimal pretreatment such as screening used either with raw sewage or with raw sewage diluted with rain water will operate efficiently and at low cost. The value of two step filtration, if any, has not been established, since results with single step filtration have been most satisfactory.

d. Test data show that the difference in flow rates between 1 and 50 micron elements having the same surface area is roughly 1:2. Thus, a system using 50 micron elements with raw sewage can be converted in the field for use as a tertiary system using 1 micron elements instead with roughly a 50% reduction in flow rate.

e. For optimum performance, hydraulic losses across the system should be minimized through the use of adequately sized plumbing and valves. This precaution will reduce the pressure required to pump liquid through the system and will also make it easier to capture soils on the surfaces of the filter element, rather than deep in the pores, where they can more readily be removed.

f. Proper materials selection is mandatory in designing an automated system for use in sewage. Filter elements of stainless steel have proven capable of operating satisfactorily in this environment, while porous brass units display limited life. The possibilities of using porous Teflon filter elements appears attractive and should be fully investigated. Other components, especially those in electrical circuits, should be protected against the corrosive fumes of H_2S.

PART II

CONCLUSIONS REGARDING THE APPROACH TO BE USED FOR A PHASED FULL-SCALE DEMONSTRATION TO EVALUATE THE SYSTEM

I. FULL-SCALE SYSTEM APPLICATIONS

The ultrasonic filtration system discussed in the previous portion of this Final Report, with proper pretreatment provisions added, has conclusively demonstrated an inherent capability of "instantaneously" treating raw sewage diluted with rain water without recourse to settling tanks or other time dependent processes. As such, the new system offers a number of interesting possibilities in treating overflows from combined and/or storm drains and in waste water treatment processes in general.

The most practical mode of operation for attacking overflow problems prevalent in cities such as Milwaukee would be to install ultrasonic filtration stations at storm by-pass structures on existing combined sewerage systems to treat by-passed combined sewage during storms. The treated effluent from the ultrasonic filtration system could be discharged to the waterway, while the recovered screenings and sludge could be returned to the interceptor sewer for subsequent removal at the community's treatment plant.

It appears also that the ultrasonic filtration system can be used in a wide variety of other applications involving waste water treatment, including those involving industrial wastes, water polishing, algae harvesting, and the like. At the Hyperion plant in Los Angeles, for example, the existing effluent after secondary treatment must be filtered if it is to be used in injection wells to replenish ground water supplies and serve as a salt water barrier. An ultrasonic filtration system at this facility could provide the required tertiary treatment.

II. FULL-SCALE DESIGN CONSIDERATIONS

As mentioned previously, the basic ultrasonic filtration element is a cylindrical canister containing a permanent-type cylindrical element. Ultrasonic energy applied periodically during normal flow conditions for approximately one second every 10 seconds is used to dislodge debris clinging to the surfaces of the filter element and thereby increase the flow.

Tests have proven that flow can be extended from four to ten times that achieved without ultrasound by the application of approximately 2 watts of ultrasonic power for each square inch of filtration surface area on a 10% duty cycle. Based on test results, it is reasonable to expect that optimized performance could be obtained in properly designed single element canisters measuring 6 inches in diameter and up to 22 or 44 inches high over-all which can exhibit filtration rates with heavily contaminated influents exceeding 10 gpm/sq ft.

These observations, which relate closely to results obtained in other ultrasonic applications, confirm the desirability of using a multiplicity of single element canisters of optimized size, power rating and cost in parallel to handle large flows of heavily contaminated liquids such as sewage. In handling average flow rates approximating 8 gpm, the 44 inch high 50 micron filter element used at Hyperion had a surface area of 1.2 sq ft yielding filtration rates ranging from 10 gpm/sq ft when clean to 7 gpm/sq ft after considerable running time on diluted sewage. Subsequent work has shown that equivalent flow can now be accommodated in a 22 inch high canister of more efficient design.

From a power standpoint during pulsing and backwashing, the 44 inch 10 gpm canister used at Hyperion and the improved 22 inch unit require a 350 watt average output power ultrasonic generator drawing 500 watts from the line power source. During normal forward flow, in a system comprised of an appropriate number of such canisters in parallel, a particular generator would energize each canister up to ten in number on a 10% duty cycle during "spritzing" and thereafter would be switched automatically to other canisters in a regular sequence. Thus, one common 350 watt output generator will serve 10 canisters of the latest design conservatively handling a flow rate of 100 gpm during normal flow. In terms of power input to the ultrasonic system, only 500 watts of power would be required for a forward flow capability of 100 gpm.

A full-scale system capable of handling 1.4 mgd forward flow can be assembled through the use of one hundred 22 inch high 50 micron canisters energized in groups of ten by ten 350 watt output ultrasonic generators requiring a total of 5 kw input from the power source. Additionally, ten separate 350 watt output ultrasonic generators would be used for backwashing, one available per bank of ten canisters as may be required. Total power demand thus would amount to 10 kw. Assuming the average cost of electricity to be 1.5¢ kwh, the daily cost of commercial power needed would approximate $3.60 for 1.4 mgd, or $2.58/mgd.

As mentioned previously, the ultrasonic filtration system operates at relatively low pressure heads. Gravity runs have been achieved with heads as low as 4 feet of water. Where gravity flow cannot be utilized, however, an analysis of the maximum pumping capability that might be required in the most conservative case should be considered. A suitable pump capable of handling a flow of 1,000 gpm against a maximum head of 50 feet of water, or 21.7 psi, would be driven by a 20 HP, 1,800 RPM drive motor. Such a motor in continuous service would require an average input of 15 kw and a maximum of 20 kw. This demand, plus a relatively insignificant amount of power required for automatic solenoid valves and other controls brings the total electrical power demand for a 1.4 mgd system with its own pumping capability to 30 kw and its cost to $10.80, or $7.74/mgd. Should the influent already exhibit even a moderate pressure head, and should certain expected equipment improvements be realized, appreciable savings in pumping costs could be anticipated.

In a 1.4 mgd system, approximately 20,000 gallons of filtered effluent would be used each day for backwashing purposes. Depending upon the source, a small 50 gpm pump would suffice to provide effluent water under adequate pressure of 25-30 psi for backwashing. The backwash water requirements will be maximized when the influent is least diluted and minimized at rainwater dilutions of 10/1 or more.

Space required for a 1.4 mgd system is minimal. Assuming that the 100 canisters of the current type are floor-mounted in a square of ten units in one direction by ten in the other, only 100 sq ft of area would be required for their installation. Stacking elements one above the other would further economize on space and building costs. Twenty ultrasonic generators plus all necessary controls could be packaged in three standard 21 inch relay racks 6 feet high. These would occupy an additional 10 sq ft of floor space. Plumbing, pumps as required, and miscellaneous components would increase the floor space slightly. Leaving adequate space for maintenance purposes and any other equipment which may be required, such as a backwash water storage tank, the system could easily fit in a building measuring some 25 x 15 feet over-all.

III. FULL-SCALE SYSTEM ACCESSORIES

Depending upon the particular application and physical location of the ultrasonic filtration system, the requirements for accessories are minimal. Pretreatment in applications involving raw sewage and overflows desirably would include bar screening followed by a detritor, both of conventional design and of low cost. These pretreatment steps that remove larger debris mechanically or by settling are more useful than a comminutor, which will place an additional and unnecessary load on the filtration system.

Pretreatment ordinarily would not be required when the ultrasonic filtration system is used for secondary or tertiary sewage treatments providing the filter elements are of at least 20 microns rating. Finer pored filters can be used with such sewage influents after a pretreatment involving flocculants which will remove colloidal material that otherwise may clog any fine pored filter element prematurely and simultaneously will reduce the level of non-settleable solids in the effluent. A simple flocculating treatment tank that will hold 30 minutes of normal flow, or 20,000 gallons for a 1.4 mgd system, plus a mixing paddle and a flocculant injector will suffice. The cost of flocculants will range from 0.5¢ per 1,000 gallons to about 2¢ per 1,000 gallons for the most highly polluted industrial waste water, according to Dow Chemical reports.

Both drinking water and certain industrial water can be filtered without any pretreatment whatsoever with elements as fine as 1 micron. Such tests, which are outside the scope of this present effort, were previously accomplished with complete success at the Santa Barbara County Water District and yielded results comparable to a diatomite filter presently used for polishing drinking water.

In all of these applications, provisions should be made for the disposal of sludge and captured solids. As mentioned previously, approximately 2% of the total forward flow through the system is used for backwashing purposes. Captured soils thus will be concentrated in the backwash effluent by a factor of 50. The sludge can be disposed of in a variety of ways, again dependent upon the particular application. In the case of a system used for treatment of combined wastes, the sludge can be stored in a simple holding tank for subsequent disposal after a storm in an existing sewer or by any other convenient means. If the system is employed alongside of a conventional waste treatment plant, the sludge can be returned to the activated sludge process. Sludge could also be disposed of by air drying in remote locations or by any other conventional method, including incineration.

Lastly, a useful accessory in a number of applications would be a standard chlorinizer for disinfecting the effluent, particularly in cases where the system is handling sewage.

IV. FULL-SCALE SYSTEM INSTALLATION AND OPERATING COST ESTIMATES

A basic 1.4 mgd ultrasonic filtration system in complete form according to the current state-of-the-art which would be capable of service in a number of diverse applications previously mentioned, as well as others, would cost less than $60,000 in mass production, the precise amount depending upon accessories required and simplifications that can be realized as the new technique matures. For purposes of this study, the total equipment, installation, 20-year financing and operating costs of two differing 1.4 mgd installations using present state-of-the-art techniques will be estimated. The first estimate will be for a 50 micron system operating on a gravity flow equivalent to a maximum head pressure of 50 feet requiring a relatively small pump for backwashing purposes only. A second estimate will consider a similar system with an added built-in forward flow pumping capability also equal to a maximum head of 50 feet, or approximately 20 psi. Excluded from both estimates are the costs of a conventional sludge disposal system and any prescreening and prestraining equipment that might be employed beneficially. Should the ultrasonic filtration plant be located adjacent to a regular waste treatment plant, such accessory facilities would most likely be available. Also omitted is the cost of land required in substantial acreage by conventional treatment plants:

Items	1. 4 mgd Gravity Flow	 Pump Flow
1. Equipment Costs		
a. 100 Canisters complete with automatic valving @ $400 each.	$ 40,000	$ 40,000
b. 20 Ultrasonic Generators @ $290 each.	5,800	5,800
c. Pumps	500	3,000
d. Controls	12,700	14,200
e. Total Equipment Costs	$ 59,000	$ 63,000
2. Installation Costs		
a. Internal and external plumbing hookups, including labor.	$ 13,000	$ 15,000

Items	1.4 mgd Gravity Flow	 Pump Flow
b. Foundation, less building.	$ 2,000	$ 2,500
c. Power installation, including labor.	5,000	6,500
d. Miscellaneous	4,000	4,500
e. Total Installation Costs	$ 24,000	$ 28,500

3. Costs per mgd, including 20-year financing costs, are derived as follows:

a. Initial Equipment and Installation Costs.	$ 83,000	$ 91,500
b. Interest @ 5% per annum for 20 years.	83,000	91,500
c. Total 20-year cost.	$166,000	$183,000
d. System Cost plus Interest over 20 years, per day.	$22.75	$25.10
e. Electricity per day @ 1.5¢/kwh*	$ 3.60	$10.80
f. One plant employee one hour per day and one man one day monthly @ $2/hr.	$ 2.53	$ 2.53
g. Maintenance plus Contingencies	$10.00	$10.00
h. Daily cost for 1.4 mgd	$38.88	$48.43
i. Costs per mgd	$27.77	$34.50
j. Costs per 1,000 gallons	2.8¢	3.5¢

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* Electric rates of the Department of Water & Power, City of Los Angeles: 2.8¢/kwh for first 300 kwh; 2.3¢ for next 700 kwh; 1.9¢ for next 2,000 kwh; 1.5¢ for next 4,200 kwh; 0.9¢ for next 9,200 kwh each month to commercial customers.

The above cost figures of between 2.8¢ and 3.5¢ per 1,000 gallons for an ultrasonic filtration system capable of handling 1.4 mgd and exhibiting an over-all performance midway between primary and secondary treatment and occupying several hundred square feet of land may be compared to published cost data for conventional primary or secondary treatment plants. These are 3¢ per 1,000 gallons for primary treatment and an additional 7¢ per 1,000 gallons or 10¢ per 1,000 gallons in total for secondary treatment excluding the value of the considerable amount of land required conventionally. No reasonable estimate can be given to land costs in various communities which range from a few dollars per acre to almost $100,000 per acre in land surrounding the Hyperion plant.

V. RECOMMENDATIONS

Recommendations which Acoustica Associates, Inc. wishes to present for consideration of the Federal Water Pollution Control Administration are as follows:

1. A full-scale mobile demonstration plant incorporating the ultrasonic filtration system and pretreatment means necessary to handle influents of raw sewage in various dilutions should be built, preferably in a mobile trailer-mounted configuration.

2. The demonstration plant should be used primarily for evaluating its performance in treating combined sewage and storm water runoff.

3. After completion of tests with combined sewage and storm water runoff, the demonstration plant should be used to evaluate its performance with micron size elements polishing water.

4. Thereafter, the demonstration plant should be used to evaluate its effectivity in treating industrial wastewater, primary sewage, secondary sewage and harvesting algae using appropriate pretreatment by flocculation. In this mode of operation, the effectivity of ultrasonic filtration assisted by the latest flocculants also can be quickly determined in treating wastes from paper and pulp mills, meat packing plants, platers, breweries, oil producers and refiners, steel and aluminum fabricators, railroads and chemical plants.

5. Demonstration plant results should be compared with those achieved with competitive systems, and detail cost comparisons should be maintained.

APPENDIX A

CONSULTANT'S TEST REPORT AND ANALYSIS

September 17, 1967
5522 Atlas Street
Los Angeles, California 90032

Acoustica Associates, Inc.
5331 West 104th Street
Los Angeles, California 90045

Gentlemen:

In early July, arrangements on behalf of Acoustica were completed with Mr. John Parkhurst, Chief Engineer and General Manager, Los Angeles County Sanitation Districts, to permit tests of their ultrasonic filtration system with sewage at the Lancaster, California, waste water treatment and reclamation plant. Tests at that facility indicated that the ultrasonic filtration system functioned with sewage. However, because of the unbearable mid-summer heat in this desert area and its distance from Los Angeles (80 miles), it was decided that testing operations should be transferred to Los Angeles to insure obtaining laboratory data having unquestioned reliability.

Following up on Acoustica's receipt of formal approval from the Los Angeles City Board of Public Works for authority to conduct tests at the City's Hyperion Plant, this consultant conferred with Mr. Norman Hume, Director of the Bureau of Sanitation, and Mr. William Garber, Acting

Superintendent of the Hyperion Plant. Full facilities were offered, including a properly valved 600 gallon tank and a 55 gallon drum in their "Headworks Building", test equipment, and sample bottles.

In an effort to locate a suitable independent testing organization to conduct a selected number of BOD, coliform and suspended solids measurements, a conference was held with one well-known Los Angeles laboratory, but apparent lack of specific experience with sewage resulted in selection of the well-regarded sanitary engineering firm of Pomeroy, Johnston & Bailey, of Pasadena, California. Sampling times and procedures to be followed by Acoustica personnel in making these measurements were established in consultation with that firm's experienced laboratory staff and with personnel at Hyperion.

TEST ARRANGEMENTS

On the theory that a simple pretreatment step is more efficient in removing coarse particulates than the ultrasonic unit, a 12 inch cubic shaped frame, covered with 14 mesh bronze screen on five of the six sides was inserted in the effluent from the plant's bar screens and detritor. This screen captured particles having a minor dimension larger than 1,200 microns.

Arrangements were made to accurately measure quantities of liquid in the 600 gallon tank. Sewage then was pumped from the above-described source to the tank. City water was used for dilution. In some tests, sand and soil were mixed with the sewage and water. A stirring device was provided and regularly used to keep particulates in suspension. There was no observable effect on filter operation from adding particulates.

A pump, taking suction from the 600 gallon tank, was arranged so the flow rate could be maintained practically constant by adjusting a valve between the pump and the filter. The filter effluent was discharged through a calibrated water meter. Inlet pressure measurements were made at the filter.

INITIAL TEST OPERATION

The 600 gallon tank was used to store mixtures of water and sewage of 2:1, 5:1 and 10:1 dilutions and in final tests of 100% sewage plus added suspended solids. Tests were run both at a constant flow rate and under conditions whereby the flow rate gradually diminished as the filter element became soiled.

Data collected by Acoustica's test engineers included periodic readings of the pressure gage, flow measuring meter and an accurate stop watch. These, and data independently recorded by the Consultant, were used in the following hydraulic analysis.

On August 22, 1967, flow tests were run using a sintered bronze filter having, according to company officials, approximately 50 micron pores. It measured 1.75 inches in diameter and 6.5 inches long, giving a surface area of approximately 36 sq in or 0.25 sq ft. The flow rate in gpm/sq ft was, therefore, four times the actual gpm.

Using 9 parts water and one part sewage, and no flow restriction, the flow rate ranged from 40 gpm/sq ft at an initial 9 psi pressure, dropping to 20 gpm/sq ft at 20 psi, after 7 minutes of operation. Repeated tests, after ultrasonic cleaning and backwashing gave the same initial flow rate but the length of run dropped to 4 to 5 minutes.

These data indicate, as would be expected, that unusually high flow rates (20 times those of diatomite filters) are possible, but with increased head losses and a requirement for more frequent backwashing.

CONTROLLED FLOW RATE TEST OPERATION

Using the same filter and dilution mentioned above and a gate valve for flow control, the flow in the next test run was kept at 3 gpm (12 gpm/sq ft). For the first 5 minutes, the gage did not show a pressure loss through the filter (head loss probably below 1 to 2 psi). The head loss reached 5 psi after 11 minutes. The arbitrarily established test-to-stop-pressure of 20 psi across the filter and a solenoid valve in series was not reached until 26 minutes of run. On the next run, this time dropped to 14 minutes after backwashing and ultrasonic cleaning. A third run continued for 5 minutes with no measureable head loss, reaching 20 psi after 16 minutes.

These tests indicated good capacity recovery by the filter and its self-cleaning system. They also, indicated a likelihood that the units could be designed for over 10 gpm/sq ft with a head loss of not to exceed 2 psi.

Subsequent tests run with a more concentrated mixture of 2 parts of water to one part of sewage and limited tests thereafter with 100% sewage plus additional suspended materials added deliberately indicated the unit when preceded by conventional fine screens would function with any concentration of suspended material which may be encountered at combined sewer overflow installations.

OBSERVATIONS, TESTS AND SELECTED LABORATORY TEST DATA

After completion of a number of test runs with raw sewage variously diluted with water to check the performance of the equipment, preparations were made to undertake a selected number of runs yielding laboratory test data on BOD, coliform and suspended solids reductions. Prior to undertaking these runs, a study was made of the results being achieved by the Hyperion facility itself.

A review of the long-term records of the Hyperion Plant indicate reasonably consistent values for BOD and suspended solids and a wide range of values for coliform. The minimum and maximum values representing 17 years of tests taken every two hours each day at selected points throughout the treatment plant are as follows:

Suspended Solids	280 to 460 mg/l averaging 360 mg/l
BOD	230 to 290 mg/l averaging 260 mg/l

Coliform - 52,000 to 1,000,000+ per ml averaging 500,000 per ml.

For each selected batch of water-sewage mixture subjected to laboratory tests, the above figures were used, together with the dilution factor, to calculate each "average value" for the filter influent. For instance, for the 10% mixture (9 parts water plus 1 part sewage) the average values of filter influent were calculated as:

BOD	26 mg/l
Suspended Solids	36 mg/l
Coliform	50,000/ml

The normal variability in laboratory test data on single samples of this type of product is great. This is due to the nature of a material having variable particle size, etc., coupled with the difficulty of always obtaining a small "representative sample". Results on 9 test samples for BOD and 5 each for both coliform and suspended solids, which we made during the course of this feasibility study, were as expected too limited in number and not uniformly consistent with the long-term calculated averages. Nevertheless, an examination of all data taken in these limited number of tests indicates consistency between the reductions observed in BOD and suspended solids at Hyperion and with reductions in suspended solids noted earlier in tests of Los Angeles water delivered to the contractor's plant.

Results of the tests of raw sewage at various levels of dilution and in concentrated form are as follows:

"10:1" Tests (10% Sewage)

Test For	Source Sample	Laboratory Test Result	Calculated "Average Value"
Coliform	Raw	145,000/ml	50,000/ml
Coliform	Thru 50 micron filter	125,000/ml	---
BOD	Raw	8.3 mg/l	26 mg/l
BOD	Thru 50 micron filter	7.2 mg/l	---
Suspended Solids	Raw	14.5 mg/l	36 mg/l
Suspended Solids	Thru 50 micron filter	5.5 mg/l	---

Analysis of "10:1" Tests

Coliform - As might be expected, a 50 micron filter is too coarse to effect significant coliform reduction. Limited field tests did indicate a nearly 50% reduction in chlorine demand and an increased efficiency of chlorination, but data are too meager to be used for other than justifying enlarging this aspect of future tests. There should be a significant improvement in chlorination efficiency by removing large numbers of particles of feces which cannot easily be penetrated by chlorine.

BOD - A 13% reduction from the laboratory test value for but a single sample on "raw" and a 72% reduction based on "average value" BOD were achieved. A value in the range of 65% is considered reasonable in terms of the more realistic reduction in suspended solids achieved in the same run.

Suspended Solids - The 62% reduction, based on the laboratory test value is a most significant one, while the 85% reduction, based upon "average value", indicates exceptional performance. Imhoff cone tests, which bore out these results, were conducted simultaneously and showed no settleable solids in the effluent and no readily visible suspended solids.

A similar analysis of a 33-1/3% mixture follows:

"2:1" Tests (33-1/3% Sewage)

Test For	Sample Source	Laboratory Test Result	Calculated "Average Value"
Coliform	Raw	720,000/ml	167,000/ml
Coliform	Thru 50 micron filter	230,000/ml	---
Coliform	Thru 50 micron filter plus 20 micron filter	300,000/ml	---
BOD	Raw	57 mg/l	87 mg/l
BOD	Thru 50 micron filter	35 mg/l	---
BOD	Thru 50 micron filter plus 20 micron filter	30 mg/l	---
Suspended Solids	Raw	52 mg/l	120 mg/l
Suspended Solids	Thru 50 micron filter	33 mg/l	---
Suspended Solids	Thru 50 micron filter plus 20 micron filter	35 mg/l	---

Analysis of "2:1" Tests

Coliform - The coliform data analysis is as discussed under the "10:1" results previously.

BOD - A 39% reduction from the laboratory test value on "raw" and a 60% reduction based upon "average value" BOD are similar to data obtained with the 10% sewage samples. The additional indicated BOD reduction achieved by passing through the 20 micron filter after 50 micron filtration is not necessarily significant but may justify further evaluation and testing of the finer filter or two step filtration to determine the most effective combination in practice.

Suspended Solids - A 37% reduction below the laboratory value on the raw sample and a 72% reduction below "average value" supports both the 2:1 BOD reading as well as data obtained with the 10:1 sewage samples showing a very satisfactory performance (compared with a 38% average reduction by Hyperion's primary sedimentation).

"Concentrated Raw" Test

Test For	Sample Source	Laboratory Test Result	Calculated "Average Value"
BOD	Raw Sewage	260 mg/1	260 mg/1
BOD	Thru 50 micron filter	82 mg/1	---
BOD	Raw Sewage plus Sludge	254 mg/1	400 mg/1
BOD	Raw Sewage plus Sludge Thru 50 micron filter	142 mg/1	---

Analysis of "Concentrated Raw" Test

BOD - The BOD reduction of raw sewage from 260 (both for the laboratory sample and "average value") to 82 mg/1 indicated a consistent

68% reduction which is close to other indicated reductions below "average values". Discounting the laboratory measurement of 254 mg/l for raw sewage plus sludge as a natural result of taking but one sample and using instead an estimated and more realistic value of 400 mg/l for the specially concentrated influent, the BOD reduction is 65%. This is a valid assumption, since a calculated amount of sludge was added to the raw sewage in an amount expected to increase the BOD by approximately 50%.

CONCLUSIONS AND RECOMMENDATIONS

The tests show:

1. Ultrasonic filters perform at relatively high flow rates and low head losses, they are cleaned and restored by established operating procedures, and they are capable of being automated.

2. Laboratory test data indicate over-all performance considerably better than primary treatment, probably intermediate between primary and secondary treatment. Average values of BOD reduction appear consistent in the range of 65% for 50 micron elements treating raw sewage subjected first to passage through coarse bar screens and a detritor.

3. The ultrasonic filtration process in combination with chlorination appears effective in reducing pollutant constituents in solid form such as coliforms and those nutrients and toxic materials which are captured by the filter elements. Approximately 65% of the solid materials in the influent applied to 50 micron elements are eliminated from the effluent.

Test data justify proceeding with the design and testing of an operational system which will function automatically. (In the Hyperion tests, backwashing involved use of city water and shut-down--There appears to be no reason why this will not be performed automatically, using filter effluent, as was done previously with the Company's test unit installed at their headquarters.)

Company engineers should establish the optimum size and configuration of units exhibiting maximum efficiency and minimum cost. Systems approaches should be undertaken to optimize flow rate, head loss, backwashing frequency, pore size, etc., for particular applications.

Tests should be made on a more extensive scale and longer term automated operation. These should be conducted to determine whether there is any long term build-up on filters and what cleaning or disinfecting or other procedures are necessary after units have been in operation.

In view of the apparently successful results and considering the importance of rapidly getting all data requisite for design, construction and operation at overflow sites, as well as for other waste water reclamation applications, it would be desirable that the next phase be conducted at Hyperion or a similar location. This would enable testing on any day (not only during storms). Company engineers could perform tests to optimize unit design and operation and obtain all operation, performance, laboratory, cost and other data with a minimum of lost time.

OTHER APPLICATIONS

Tests on algae removal from Los Angeles City water with the unit having small pores appeared to surpass a vertical carbon filter in removing algae after coagulation. Other small-scale tests all indicate a potential in many fields. An especially promising field is, for example, removing particulates from secondary effluents, while another would be to "polish" primary effluent (in combination with chlorination) where full secondary treatment is not necessary.

Respectfully submitted,

Charles L. Senn, P. E., M. S.
Consultant in Civil and Sanitary Engineering

APPENDIX B

SUMMARY OF TEST RUNS

TABULATION OF TEST RUNS

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm		Total Flow Gallons	Remarks
				Start	End		
1	Acoustica	Tap water +AC Dust	5/10 μ wire cloth	8.8	6.0	308	
2	Acoustica	Tap water + AC Dust	5/10 μ wire cloth	5.6	5.2	79.5	wire cloth evaluation 1.5 gr.
3	Acoustica	Tap water + AC Dust	1/10 μ sintered porous	7.3	1.1	518	3.5 gr. AC Dust
4	Acoustica	Tap water only	1/10 μ sintered	7.3	3.0	158	With 10 sec. pulses
5	Acoustica	Tap water only	5/10 μ wire mesh	6.9	3.0	485	No ultrasound or spritz
6	Acoustica	Tap water only	5/10 μ wire mesh	6.9	0.6	23	No ultrasound or spritz
7	Acoustica	Tap water only	1/10 μ sintered	7.2	0.75	39	No ultrasound or spritz
8	Acoustica	Tap water only	1/10 μ sintered	5.6	3.2	321	With ultrasound and spritz
9	Acoustica	Tap water only	5/10 μ wire cloth	7.7	3.7	141	With ultrasound and spritz
10	Acoustica	Tap water only	5/10 μ wire cloth	7.7	3.5	139	With ultrasound and spritz
11	Acoustica	Tap water only	5/10 μ wire cloth	7.4	3.3	143	With ultrasound and spritz

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm		Total Flow Gallons	Remarks
				Start	End		
12	Acoustica	Tap water only	5/10 μ wire cloth	7.7	4.4	166	With ultrasound and spritz
13	Acoustica	Tap water only	5/10 μ wire cloth	7.6	5.1	170	With ultrasound and spritz
14	Acoustica	Tap water only	5/10 μ wire cloth	7.8	5.2	170	Half power test (Ultrasound at .707 on scope)
15	Acoustica	Tap water only	5/10 μ wire cloth	7.3	4.1	75	Spritz only, no ultrasound. Filter cleaned at half-power (.707)
16	Acoustica	Tap water only	1/10 μ sintered porous	5.8	3.8	67	Full ultrasound power and spritz.
17	Acoustica	Tap water only	1/10 μ sintered porous	5.5	3.8	70	Full ultrasound power and spritz.
18	Acoustica	Tap water only	1/10 μ sintered porous	5.4	3.8	52	Full ultrasound power and spritz.
19	Acoustica	Tap water only	1/10 μ sintered porous	5.9	3.8	165	Full ultrasound power and spritz.
20	Acoustica	Tap water only	1/10 μ sintered porous	6.1	3.7	120	Full ultrasonic power and spritz.
21	Acoustica	Tap water only	1/10 μ sintered porous	6.0	3.85	71	Full ultrasonic power and spritz.

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm Start	Flow Rate, gpm End	Total Flow Gallons	Remarks
22	Acoustica	Tap water only	1/10 μ sintered porous	5.55	3.8	102	Full Ultrasonic Power and spritz.
23	Acoustica	Tap water only	1/10 μ sintered porous	5.6	3.7	85	Full ultrasonic power and spritz.
24	Acoustica	Tap water only	5/10 μ wire cloth	7.3	6.5	80	No spritz valve action - Ultrasound on every 10 sec.
25	Acoustica	Tap water only	1/10 μ sintered porous	6.8	3.8	142	Spritz changed to 1/2 sec. pulses.
26	Acoustica	Tap water only	5/10 μ wire cloth	8.4	3.7	116	Spritz changed to 1/2 sec. pulses.
27	Acoustica	Tap water only	1/10 μ sintered porous	6.6	4.5	195	1 sec. spritz pulses with ultrasound.
28	Acoustica	Tap water only	1/10 μ sintered porous	6.5	3.9	177	1 sec. spritz pulses with ultrasound
29	Acoustica	Tap water only	1/10 μ sintered porous	6.4	4.3	182	1 sec. spritz pulses with ultrasound.
30	Acoustica	Tap water only	1/10 μ sintered porous	6.1	4.1	178	1 sec. spritz pulses with ultrasound
31	Acoustica	Tap water only	1/10 μ sintered porous	6.1	4.2	178	1 sec. spritz pulses with ultrasound

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm		Total Flow Gallons	Remarks
				Start	End		
32	Lancaster	Primary Effluent	10μ nominal sintered	1.6	0.5	10	1 sec. spritz pulses with ultrasound not pre-screened.
33	Lancaster	Primary Effluent	10μ nominal sintered	2.5	1.0	15	1 sec. spritz pulses with ultrasound not pre-screened.
34.	Lancaster	Primary Effluent	10μ nominal sintered	1.3	0.5	5	Influent much dirtier.
35	Lancaster	Primary Effluent	10μ nominal sintered	3.0	0.5	25	Influent diluted 5:1
36	Lancaster	Primary + $FeCl_3$	20μ sintered	6.75	4.75	45	55 gallon drum
37	Lancaster	Primary + $FeCl_3$	1μ sintered	6.5	3.0	46	55 gallon drum
38	Lancaster	Algae Pond III + $FeCl_3$	1μ sintered	3.5	0.2	8	55 gallon drum, Floc not complete and not settled
39	Acoustica	Tap water	1μ sintered (2 ea.)	8.2	4.0	275.5	Rectangle canister - 2 elements 3/4 HP pump
40	Acoustica	Tap water	1μ sintered (2 ea.)	14.0	4.5	210	Rectangle canister - 2 elements 3 HP pump
41	Acoustica	Tap water	1μ sintered (2 ea.)	10.9	4.3	137	Rectangle canister - 2 elements 1-1/2 HP pump
42	Acoustica	Tap water	1μ sintered (2 ea.)	8.8	3.9	118	Rectangle canister - 2 elements 3/4 HP pump
43	Acoustica	Tap water gravity flow	20μ bronze	4.0	3.8	148.9	10" canister, gravity flow

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm Start	Flow Rate, gpm End	Total Flow Gallons	Remarks
44	Acoustica	Tap water	6" 5μ bronze	9.5	3.6	374	Test aborted because generator and canister not matched
45	Acoustica	Tap water	6" 5μ bronze	9.0	8.1	168	Test aborted because generator and canister not matched.
46	Hyperion	Sewage diluted 2:1	100μ bronze	8.2	2.2	56	14 mesh pre-screen
47	Hyperion	Sewage diluted 10:1	100μ bronze	8.5	5.0	49	14 mesh prescreen - 1 backflush cycle
48	Hyperion	Sewage diluted 10:1	100μ bronze	8.5	5.0	41.5	14 mesh pre-screen - 1 backflush cycle
49	Hyperion	Sewage diluted 10:1	100μ bronze	8.0	5.0	19	14 mesh pre-screen - 2 backflush cycle
50	Hyperion	Sewage diluted 10:1	100μ bronze	8.0	4.0	30	14 mesh pre-screen - 2 backflush cycle
51	Hyperion	Sewage diluted 10:1	100μ bronze	2.0-3.0	3.0	72	Outlet of pump throttled down 1 backflush cycle
52	Hyperion	Sewage diluted 10:1	100μ bronze	3.0	3.0	40	Outlet of pump throttled down 2 backflush cycles

Test Run No.	Location	Influent	Filter Element	Flow rate, gpm Start	End	Total Flow Gallons	Remarks
53	Hyperion	Sewage diluted 10:1	100 μ bronze	3.0	2.0	52	Outlet of pump throttled down.
54	Hyperion	Sewage diluted 5:1	100 μ bronze	3.4	2.6	23	Outlet of pump throttled down.
55	Hyperion	Sewage diluted 5:1	50 μ bronze	3.2-4.6	3.1	143	Outlet of pump throttled down.
56	Hyperion	Sewage diluted 5:1	50 μ bronze	4.8	1.1	29	Outlet of pump throttled down. No ultrasound, no spritz
57	Hyperion	Sewage diluted 2:1	50 μ bronze	4.0	2.4	72.5	Outlet of pump throttled down No ultrasound, no spritz
58	Hyperion	Sewage diluted 10:1	50 μ bronze	3.8	2.2	142	Outlet of pump throttled down. BOD samples.
59	Hyperion	Sewage diluted 10:1	50 μ bronze	2.5-3.3	1.0	122	Outlet of pump throttled down.
60	Hyperion	Sewage diluted 10:1	50 μ bronze	3.0-4.0	2.9	41	Outlet of pump throttled down. Flow rate check after backflush (ultrasound off)
61	Hyperion	Sewage diluted 2:1	50 μ bronze	1.1	0.7	53	Outlet of pump throttled down.

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm Start	Flow Rate, gpm End	Total Flow Gallons	Remarks
62	Hyperion	Sewage diluted 2:1 thru 50μ first	20μ 20" bronze	5.0	5.0	46.7	Outlet of pump throttled down. 350 watt generator, new transducer. BOD samples. Ran out of samples.
63	Hyperion	Sewage diluted 2:1	50μ bronze	1.5	1.0	16.7	Outlet of pump throttled down. No ultrasound, no spritz
64	Hyperion	Sewage diluted 10:1	50μ bronze	5.1	3.3	36.9	No ultrasound, no spritz
65	Hyperion	Sewage diluted 10:1	50μ bronze	3.4	2.9	36.5	No ultrasound, no spritz
66	Hyperion	Sewage diluted 10:1	20μ 20" bronze	5.8	5.9	72	Aborted by bad leak
67	Hyperion	Sewage diluted 10:1	20μ 20" bronze	7.3	4.3	162	
68	Hyperion	Sewage diluted 10:1	20μ 40" bronze	9.4	5.0	213.1	350 watt generator, new transducer
69	Hyperion	Sewage diluted 10:1	20μ 40" bronze	8.0	5.3	61.4	Spray ring test with spray valve shut off.
70	Hyperion	Raw sewage, no dilution	20μ 10" bronze	3 minute run only		14	350 watt generator, new transducer

Test Run No.	Location	Influent	Filter Element	Flow Rate, gpm		Total Flow Gallons	Remarks
				Start	End		
71	Hyperion	Raw Sewage, plus extra sludge	20μ10" bronze	3 minute run only		2	350 watt generator, new transducer

NOTE: Spritz is periodical one second pulse of ultrasound and closing of inlet and outlet while opening drain valve.

APPENDIX C

PROCEDURE FOR EVALUATING SUSPENDED SOLIDS

3.2.2 The part or parts are inspected using an ultraviolet light source of 2500 to 3700 Angstrom units. Any evidence of fluorescence shall be cause for recleaning.

3.3 Wipe Test Inspection.

3.3.1 A sample area of the part or parts is wiped firmly with a hard filter paper (Schleichor and Schule, #602 or equivalent). If any contamination is observed the part will be recleaned.

3.4 Rinse Test Inspection.

3.4.1 Equipment

Filter Holder - Pyrex, with a fritted glass base, 960 MM^2 filtration area, rubber stopper, holding clamp and 250 ml glass funnel. (Millipore Filter Corp., Cat #XX10 047 00, or equivalent).

Cover - Glass, for 250 ml funnel.

Filter - Blue and black with grid, 47 mm diameter, (Millipore Filter Corp., Type HABG, or equivalent) 0.45 micron rating.

Vacuum Flask - 1000 ml heavy wall, "Pyrex".

Vacuum Pump - 27 inches of mercury, minimum capacity (Millipore Filter Corp., # XX60 000 00 or equivalent).

Microscope - Complete with a mechanical stage, and capable of magnifications of 30 to 45X and 100 ± 10X using 10X ocular lens. Most suitable equipment is a binocular microscope; however, a monocular microscope may be used.

Measuring Eyepiece - Ocular Micrometer - 10 mm scale divided into 100 units, (A. O. Spencer 1406A or equivalent).

Stage Micrometer - Microscope, 0. 1 to o. ol mm rulings Bausch and Lomb #31-16-90 or equivalent.

Lamp - Microscope - With variable intensity and position adjustable, American Optical #370B or equivalent.

Forceps - Stainless steel with unserrated tips. (Millipore Filter Corp.).

Petri Dish - Plastic, disposable (Millipore Filter Corp. , Cat. # PD10-047-00, or equivalent).

Dust Cover - Microscope and Accessories.

Solvent Filtering Dispenser - Glass with Swinney Filter Holder (Millipore XX66 000 00 or equivalent).

Jar - Glass, wide mouth with screw cap, 4 oz.(Braun Cat. # 16188 or equivalent).

Foil - Aluminum

Slide - Glass 2 x 3

Filter - White, 13 mm (Millipore Type SM or equivalent).

Analytical Balance.

Constant Temperature Oven.

3. 4. 2 Procedure

3. 4. 2. 1 Particle size analysis. Particle size determination is made by filtering the test of sample solvents (200mh) through a millipore type HABG filter.

3.4.2.2 Procedure for Particle Counts.

(a) Place one filter disc from its container, grid side up on the filter holder.

(b) Pour solution into the funnel.

(c) Turn on vacuum and rinse sides of funnel with appropriate rinsing fluid.

(d) When solution has passed completely through the filter, turn off vacuum pump and remove filter to a clean petri dish, or clean glass slides.

(e) Place filter under microscope and check, per paragraph 5.5.6. Filter shall meet all requirements of customers specification.

3.4.2.2.1 Total Filterable Solids Weights Determination Procedure.

(a) Record the weight of a blank filter.

(b) Follow steps (a) through (d), paragraph 3.4.2.2.

(c) Place the petri dish with the filter in the oven.

(d) "Crack" the lid of the petri dish to allow moisture to escape.

(e) Dry at 120° for 30 minutes.

(f) Remove from oven and allow temperature to stabilize for 10 minutes.

(g) Weigh the filter with the total filterable solids on it.

(h) The difference in weight between the the filter before and after weighing is the T. F. S.

3. 4. 2. 3 Non-volatile residue determination The degree of cleanliness of parts being processed shall be analyzed using a control test fluid prepared and controlled by the Quality Control Department. Trichloroethylene when used as a control fluid shall not contain more than .010 grams per 500 ML of non-volatile residue.

3. 4. 3 Equipment

(a) Beaker 800 ml, pyrex or equal

(b) Flash evaporator.

(c) Laminar flow bench.

(d) Constant temperature oven.

(e) Anlytical balance, accuracy to 1/10 milligram.

(f) Desiccator.

(g) Tongs, stainless steel.

3. 4. 4 Non-volatile residue. The filtrate from the reliability tests or the 500 ml sample of test solution shall be analyzed for non-volatile residue content in the following manner:

(a) Transfer 500 ml of the fluid to a clean degreased 800 ml beaker, cover beaker with a clean watch glass and transfer to the non-volatile residue area. Transfer the 500 ml of fluid to the flash evaporater which is located on the laminar flow bench.

(b) Evaporate the fluid to 10 to 20 ml using the flash evaporator.

Note: Before starting flash evaporator, make sure to vacuum source is on and attached to flash evaporator.

(c) Transfer the fluid to a constant weight (within 0. 3 mg) tared weighing bottle weighed to the nearest 0. 1 mg and cover with a cleaned watch glass. This work will be accomplished on the laminar flow bench.

(d) Place the weighing bottle in a constant temperature oven at 221-230°F until evaporation is complete,

(e) Cool the weighing bottle in a desiccator for a minimum of 30 minutes and then weight to the nearest 0. 1 mg.

(f) The difference in weight of non-volatile shall not be greater than the increase specified for the affected item.

(g) The gain in weight is recorded in milligrams per 100 ml of sample. This figure multiplied by 10 and divided by the specific gravity of the sample submitted will be the ppm, by weight.

3.4.5 Allowable Contamination.

3.4.5.1 Unless otherwise specified, particle contamination per square foot of surface area flushed with 500 ML of test fluid shall not exceed the customers specifications.

- Particles are defined as any foreign material and micron limitation applies to any dimension of the particle.
- Samples with significant area of less than one square foot shall be analyzed using test fluid in accordance with the following schedule:

Sample Surface Area (sq. in.)	ML Test Fluid
14.4	50
28.8	100
43.2	150
57.6	200
72.0	250
86.4	300
100.8	350
115.2	400
129.6	450
144.0	500

3.4.5.2 The non-volatile residue contamination on the surface being sampled shall not exceed .001 grams per square foot of surface area.

3.4.6 The influent and effluent of the water ph of the final water rinse shall meet the requirements of paragraph 3.7, document B. To check ph value of water use the following steps.

(a) Standardize the Beckman Instrument using a buffer solution of known ph.

(b) Depress standby button.

(c) Rinse the Electrodes and Thermo-Compensator in distilled water.

(d) Immerse same in sample solution.

(e) Depress read push-button and read ph valve from meter.

Note:
1. Where possible, test fluid shall be accumulated to make up the standard 500 ML analysis schedule solution.
2. Non-volatile residue determination shall be extrapolated to conform to percent of fluid analyzed.
3. Test sampling shall be made in the clean room in conformance with the requirements of this specification.
4. Analysis of test fluids may be performed outside the clean room provided test samples are not contaminated by exposure to the atmospheric environment.

3.4.7 Quality Assurance

3.4.7.1 All results will be noted on Form #5.

3.4.8 Surveillance for conformance to the requirements section and maintenance of test fluids and test records shall constitute Quality Assurance provisions. Failure to comply with requirements shall be cause for ceasation of operation until discrepancies are corrected.

3.4.8.1 Any parts that fail to meet the requirements of the rinse test (paragraph 3.4) shall be recleaned and retested.

3.5 Reference Test

3.5.1 Samples are collected of the effluent final rinse as well as a blank sample of the rinse solvent (minimum 500 ML). The samples are forwarded to an approved laboratory for tests.

3.6 50 - Mesh Screen Test

3.6.1 A quantity of the effluent from the final rinsing (approximately 500 ML per square foot of surface area) is passed through a 50 - mesh screen (ASTM-E11-61). The top side of the screen is inspected and no particles shall be visible on the screen.

4.0 CONTROL OF MATERIALS AND PROCESSING FLUIDS

4.1 Solution analyses are performed per paragraph 3.4.

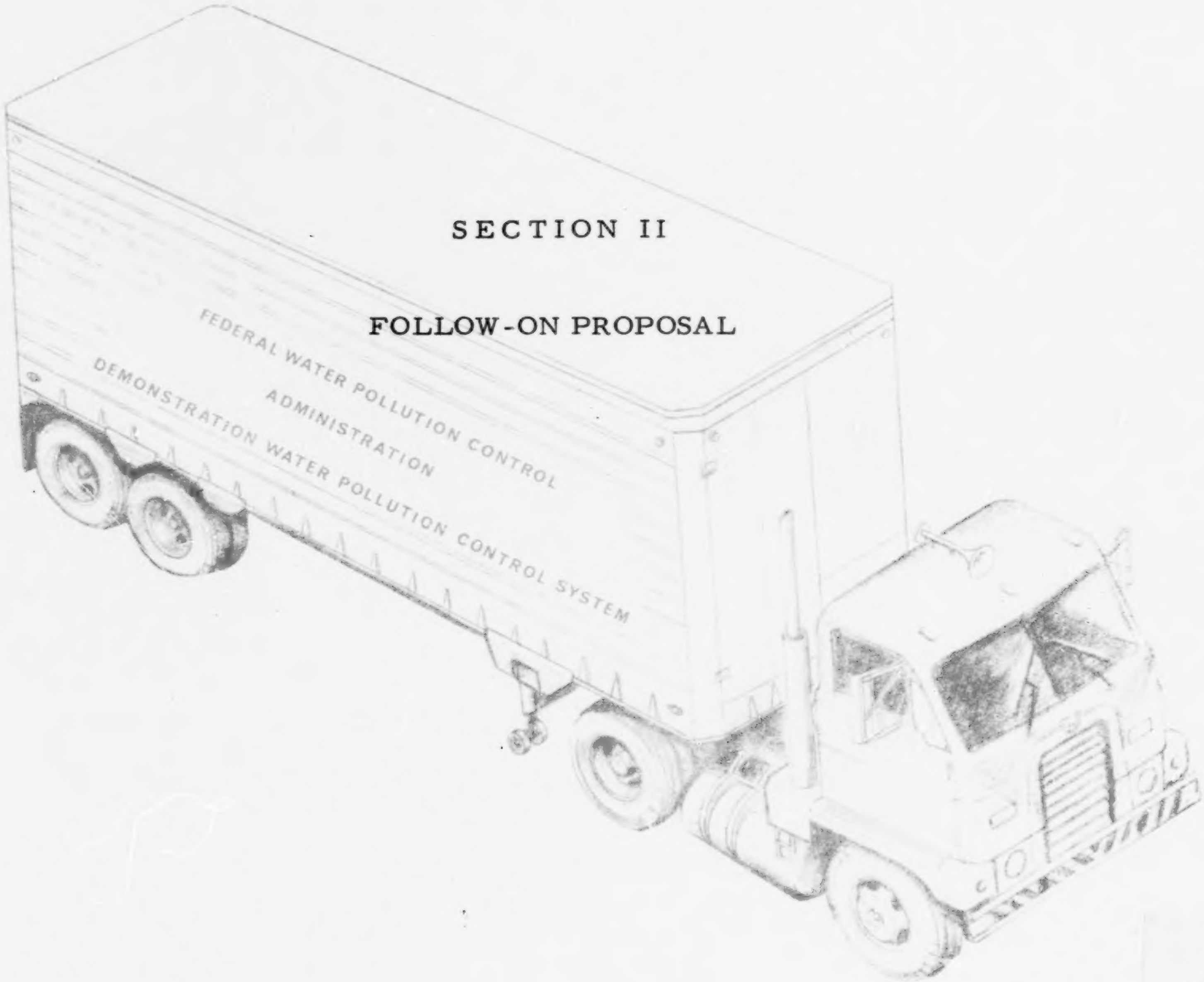
4.2 Frequency of analysis or change.

4.2.1 Trichloroethylene used in cleaning and vapor degreasing tanks is changed when it fails to meet the following requirements.

(a) Boiling point - boiling temperature shall not exceed 92°C.

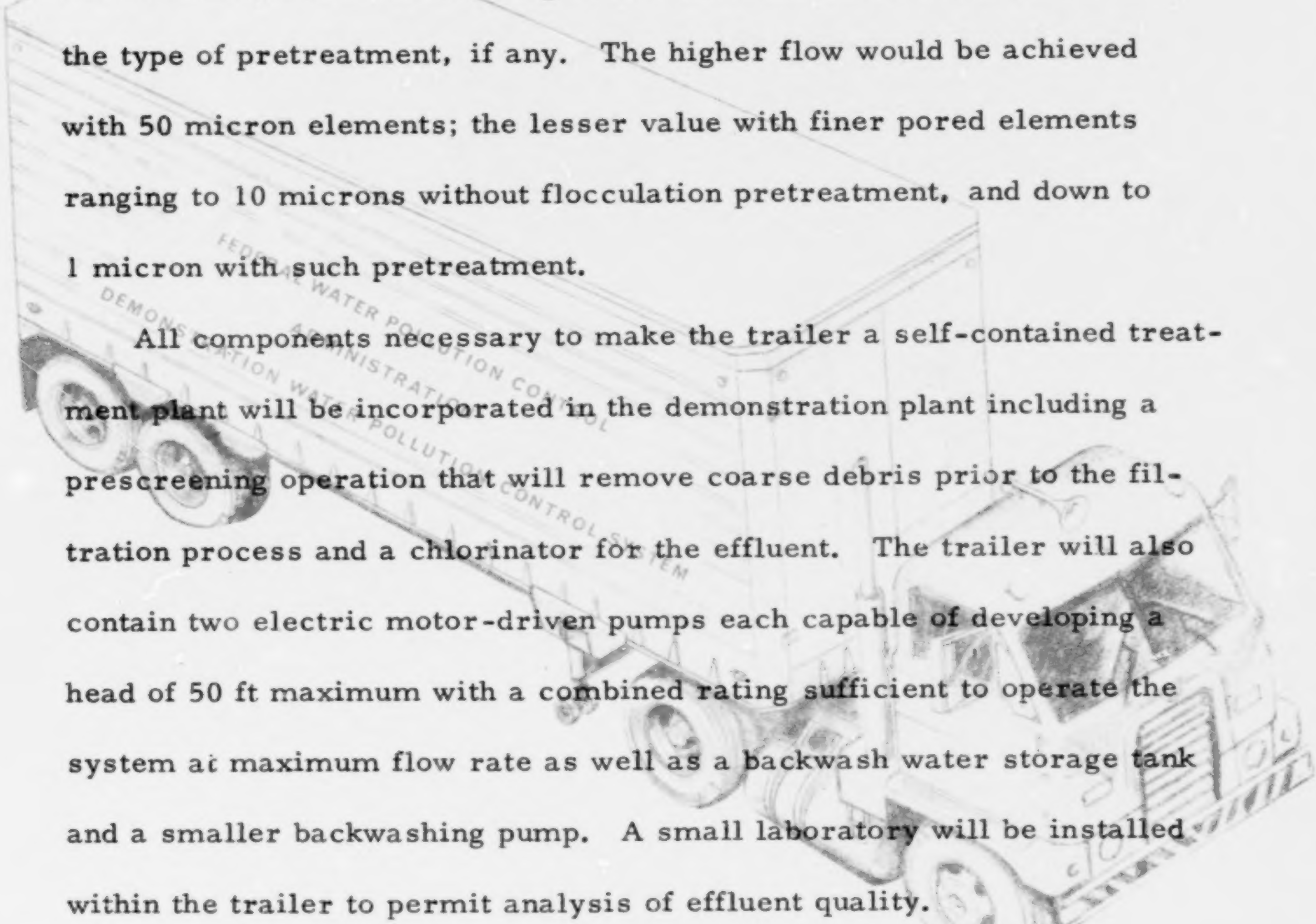
SECTION II

FOLLOW-ON PROPOSAL


FEDERAL WATER POLLUTION CONTROL
ADMINISTRATION
DEMONSTRATION WATER POLLUTION CONTROL SYSTEM

I. PROPOSED DEMONSTRATION SYSTEM

a. General Description - The proposed demonstration system employing ultrasonic filtration will be a self-contained, trailer-mounted installation capable of handling between 200 and 400 gpm, or 288,000 to 576,000 gpd, of contaminated water, including combined sewage and storm water runoff, the precise capacity depending upon the nature of the influents, the micron rating of the filter elements employed, and the type of pretreatment, if any. The higher flow would be achieved with 50 micron elements; the lesser value with finer pored elements ranging to 10 microns without flocculation pretreatment, and down to 1 micron with such pretreatment.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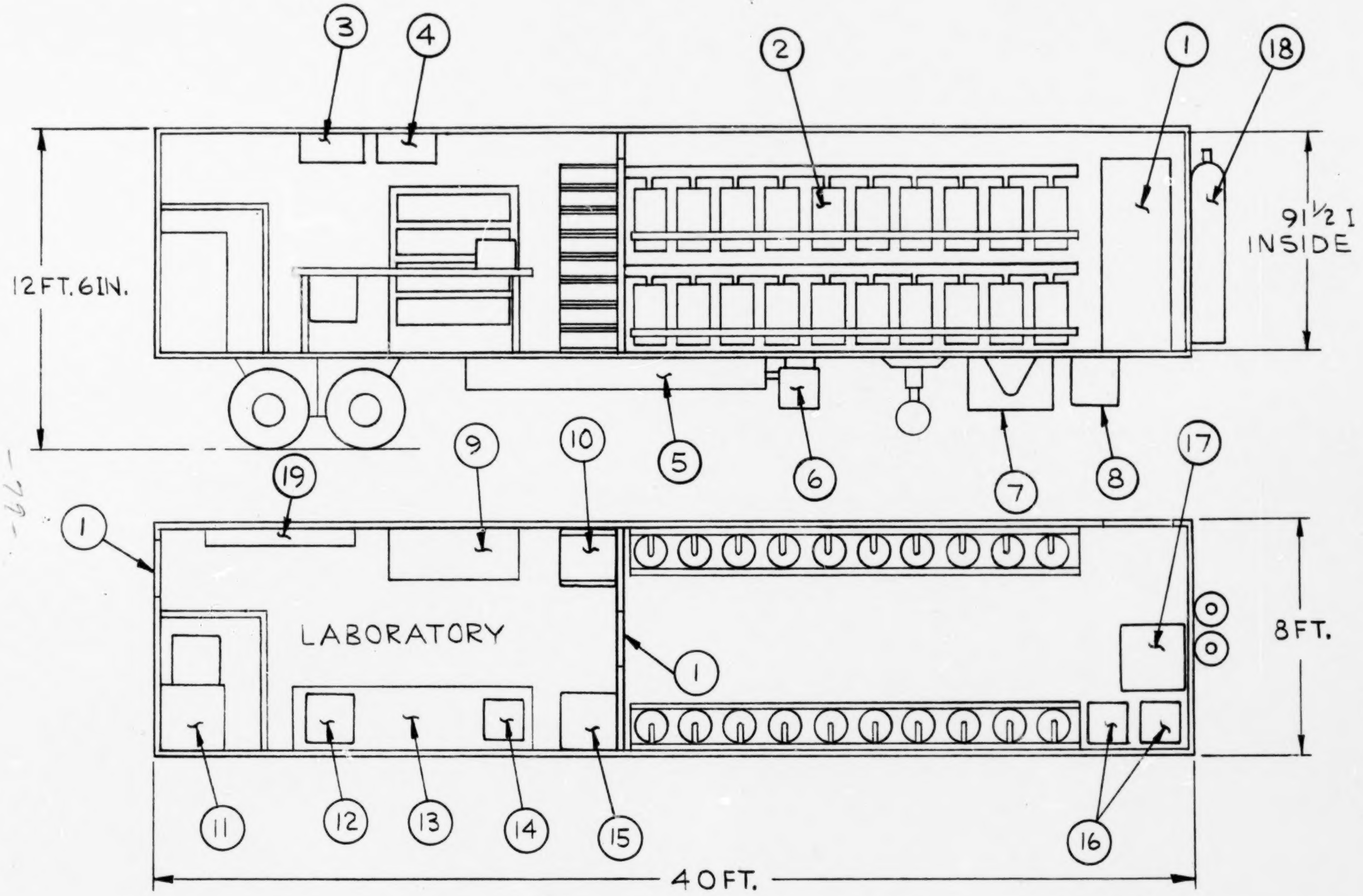
DEMONSTRATION WATER POLLUTION CONTROL SYSTEM

All components necessary to make the trailer a self-contained treatment plant will be incorporated in the demonstration plant including a prescreening operation that will remove coarse debris prior to the filtration process and a chlorinator for the effluent. The trailer will also contain two electric motor-driven pumps each capable of developing a head of 50 ft maximum with a combined rating sufficient to operate the system at maximum flow rate as well as a backwash water storage tank and a smaller backwashing pump. A small laboratory will be installed within the trailer to permit analysis of effluent quality.

In operation, an influent of combined sewage and storm water would be fed to the trailer through an 8 inch pipe connection. A similar size pipe connection would serve to exhaust the treated effluent to a selected point of disposal. Captured sludge collected in the prescreening and filtration processes would exhaust through a third smaller pipe connection for disposal. Backwashing will be accomplished using effluent collected after the ultrasonic filtration step. The only input other than the influent required to operate the system and operate the air conditioner would be 15 kw of electrical power from a 220/440 volt, 3 phase, 60 Hz source.

b. Trailer - A standard trailer as shown in Figure 9-1 is proposed for the demonstration plant. Measuring 40 ft in length, 12 ft, 6 in in height over-all and 8 ft in width, and will be fabricated in the main of aluminum. This size trailer will be permitted full access to any roads within the United States and can be hauled by a conventional tractor which can be leased for this purpose as the need for changing locations occurs.

c. Pretreatment Screening - In order to reduce the load imposed on the ultrasonic filtration system by coarse influent debris, such as paper, wood, leaves and similar material, a simple rotary prescreening device will be built and installed underneath the trailer. This unit will be provided with stainless steel screen of 20 mesh having openings of 825 microns through which influent will be passed in the manner shown in the sketch. Debris collecting on the mesh will be removed by a series


3
4
2
1
18
12FT.6IN.
9 1/2 I INSIDE
5
6
7
8
9
10
19
17
1
LABORATORY
1
8FT.
11
12
13
14
15
16
40FT.

SEE FOLLOWING PAGE FOR
COMPONENT IDENTIFICATION

FIG. 9-1
PROPOSED MOBILE
DEMONSTRATION SYSTEM

Figure 9-2

COMPONENT IDENTIFICATION

PROPOSED MOBILE DEMONSTRATION SYSTEM

1. Access Doors
2. Ultrasonic Filter (40 Modules)
3. Distilled Water Tank for Laboratory Use
4. Fresh Water Tank for Laboratory Use.
5. 900 Gallon Backwash Storage Tank
6. Backwash Pump
7. Prescreen Treatment Unit
8. Air Compressor
9. General File Cabinet and Desk
10. Ultrasonic Generator Rack
11. Air Conditioner (5 ton)
12. Sink
13. General Work Bench
14. Incubator Oven for BOD
15. Electronic Controllers
16. Main Pumps
17. Chlorine Injector System
18. Chlorine Bottles (2 ea.)-Mounted Outside Trailer
19. Full View Control Panel

of high pressure nozzles spraying fully treated effluent derived from the 900 gallon capacity backwash storage tank which will be energized by a pump capable of delivering 25 gpm continuously at a pressure of 50 - 75 psi. At maximum demonstration plant flow capacity, the amount of backwash water required to clean the pretreatment screening drum and the ultrasonic filters will be less than 5% of total flow. Debris and sludge removed from the screen will be exhausted for subsequent disposal. The entire screening system will be fabricated of corrosion-resistant materials and will be fully contained within a stainless steel cover to minimize odors and the generation of light-activated slimes.

d. Ultrasonic Filtration System - The proposed demonstration system would employ an optimized configuration of ultrasonic filtration modules in ten groups of four modules each which will be mounted within the trailer as shown in Figure 9-1. Each module will have an over-all height of 26 in and a body diameter of 6 in. The permanent filter element used in each module will be 20 in in height and will have an outer diameter of 1.75 in to yield an effective filtration area of 0.75 sq ft. Elements will be fabricated of either stainless steel or possibly Teflon which shows promise as an ideal media in terms of corrosion immunity and low head loss.

To simplify the construction of the system and reduce costs, four modules will form a group having a common set of solenoid actuated valves in the influent, effluent and drain lines. Ten such groups would comprise the total ultrasonic filtration system. During normal forward flow of the entire system, each group of four modules would be ultrasonically pulsed for one second each ten seconds to enhance the flow and lengthen the time between required backwash cycles. When a particular group of four modules requires backwashing, the group will automatically enter this cycle and return to service after the several minutes required to restore the elements to the clean condition. One group of four modules can be backwashed at a time.

In order to increase the usefulness of the demonstration system, construction will be simplified to the point where filter elements of varying pore size can be installed in any group of modules in a matter of minutes. From feasibility studies reported upon previously, an optimized pore size for treating raw sewage diluted in varying degrees with water is in the order of 50 microns, but smaller pore sizes may prove to be more useful in actual field operations and in serving as treatment of various waste waters.

From a construction standpoint, each filter canister will be constructed of steel suitably protected against corrosion. Inlet and outlet lines of each module will be of 1-1/4 in pipe to minimize pressure drop across the system. Each group of four modules will be connected to larger manifold lines having sufficient diameter to minimize losses in the plumbing system. A design goal will be a total head loss across the entire ultrasonic filtration system of under 5 psi with clean elements and maximum system flow being accommodated. Under normal operating conditions, the maximum pressure loss across the system will be maintained below 20 psi.

The following table summarizes flow data expected with various filter elements that may be employed in practice:

Pore Size (Microns)	Average Flow per Module (gpm)	Average Flow for System (gpd)
1	3	172, 800*
5	5	288, 000
20	8	470, 800
50	10	576, 000

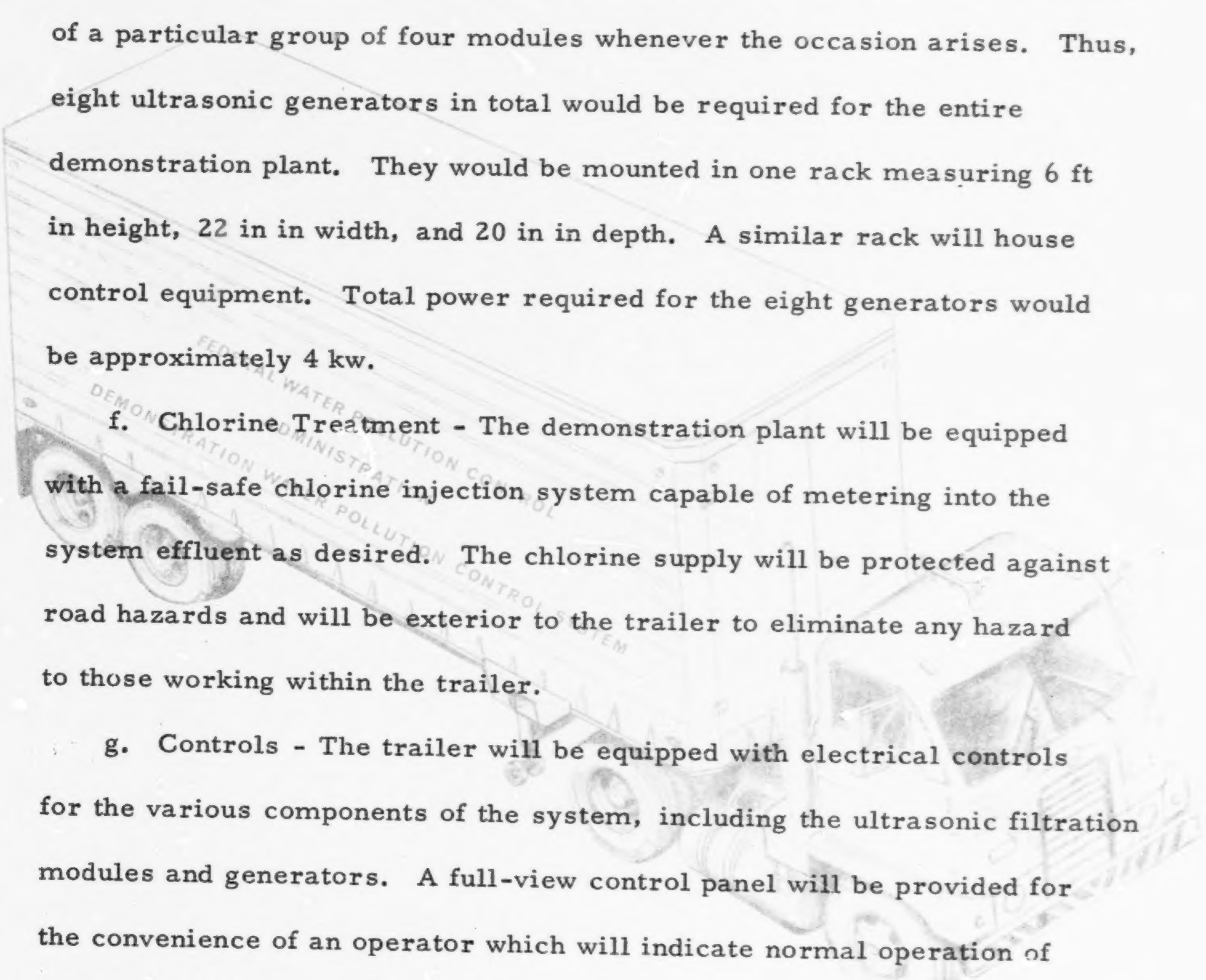
* 1 micron element is considered useful for advanced tertiary treatment and water polishing.

e. Ultrasonic Generators - Recent tests of optimized ultrasonic filtration configurations have shown the desirability of using separate ultrasonic generators for each module being energized rather than a common generator of higher power rating energizing a group of modules. The use of an individual generator-module insures an optimized transfer of energy to the region surrounding a particular filter element irrespective of changes in environment that may occur in neighboring modules. This is of particular importance in the treatment of sewage which most benefits by the application of ultrasonic energy in backwashing cycles. Accordingly, four ultrasonic generators each rated at 350 watts output would be employed to energize all forty modules in succession during forward flow, each group of four being energized successively for one second every ten seconds.

A second group of four 350 watt generators would perform backwashing of a particular group of four modules whenever the occasion arises. Thus, eight ultrasonic generators in total would be required for the entire demonstration plant. They would be mounted in one rack measuring 6 ft in height, 22 in in width, and 20 in in depth. A similar rack will house control equipment. Total power required for the eight generators would be approximately 4 kw.

f. Chlorine Treatment - The demonstration plant will be equipped with a fail-safe chlorine injection system capable of metering into the system effluent as desired. The chlorine supply will be protected against road hazards and will be exterior to the trailer to eliminate any hazard to those working within the trailer.

g. Controls - The trailer will be equipped with electrical controls for the various components of the system, including the ultrasonic filtration modules and generators. A full-view control panel will be provided for the convenience of an operator which will indicate normal operation of all facets of the system as well as flow rate, head loss and other operating parameters. The entire system will be energized by one main circuit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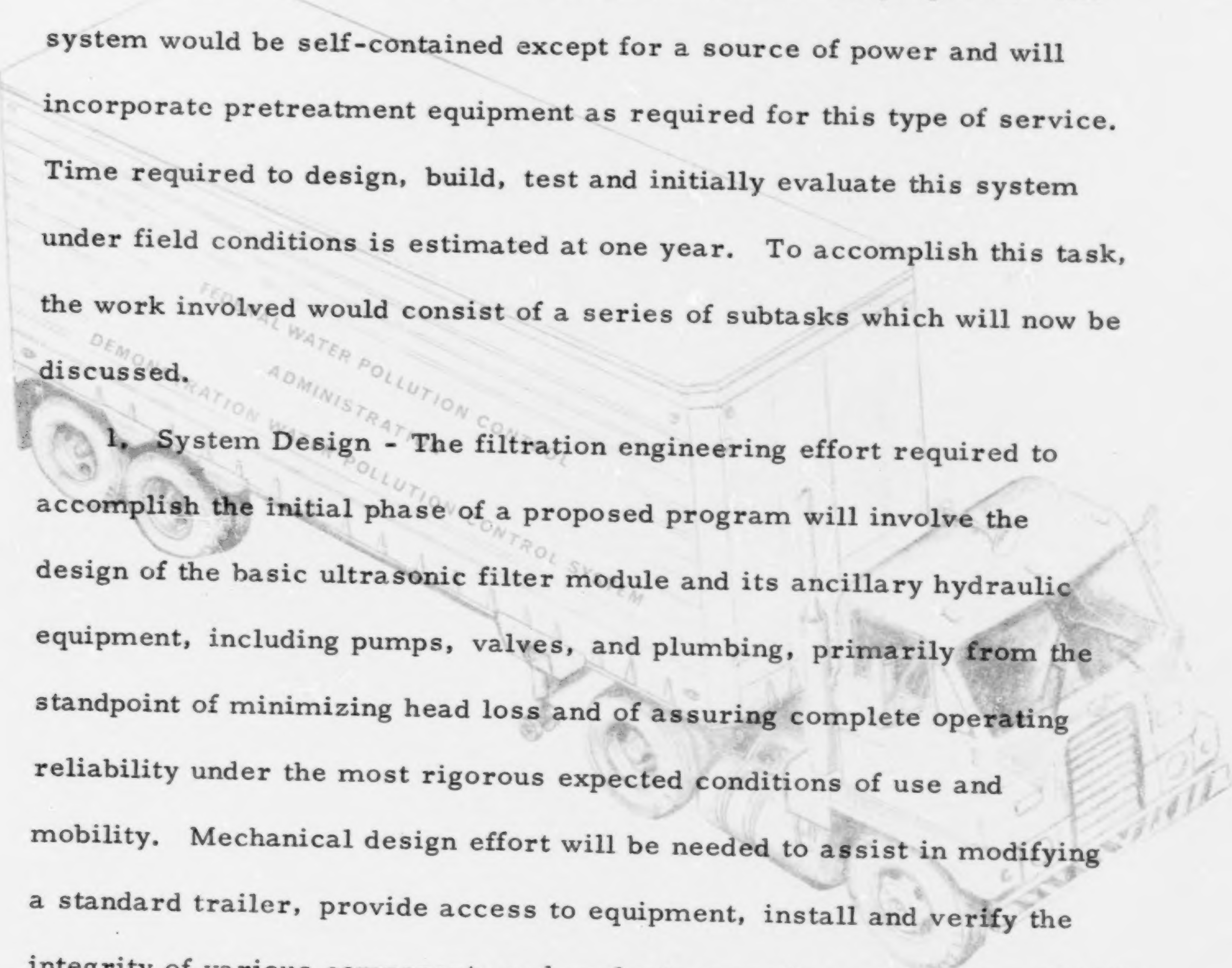
DEMONSTRATION WATER POLLUTION CONTROL SYSTEM

breaker with individual components, including pretreatment, ultrasonic filtration and the chlorinator being individually controllable if so desired.

II. PROPOSED STATEMENT OF WORK

Program Scope - A program involving the design, manufacture, and evaluation of a mobile, trailer-mounted ultrasonic filtration system for treating combined sewage and storm water runoff is proposed. The system would be self-contained except for a source of power and will incorporate pretreatment equipment as required for this type of service. Time required to design, build, test and initially evaluate this system under field conditions is estimated at one year. To accomplish this task, the work involved would consist of a series of subtasks which will now be discussed.


FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEMONSTRATION WATER POLLUTION CONTROL SYSTEM

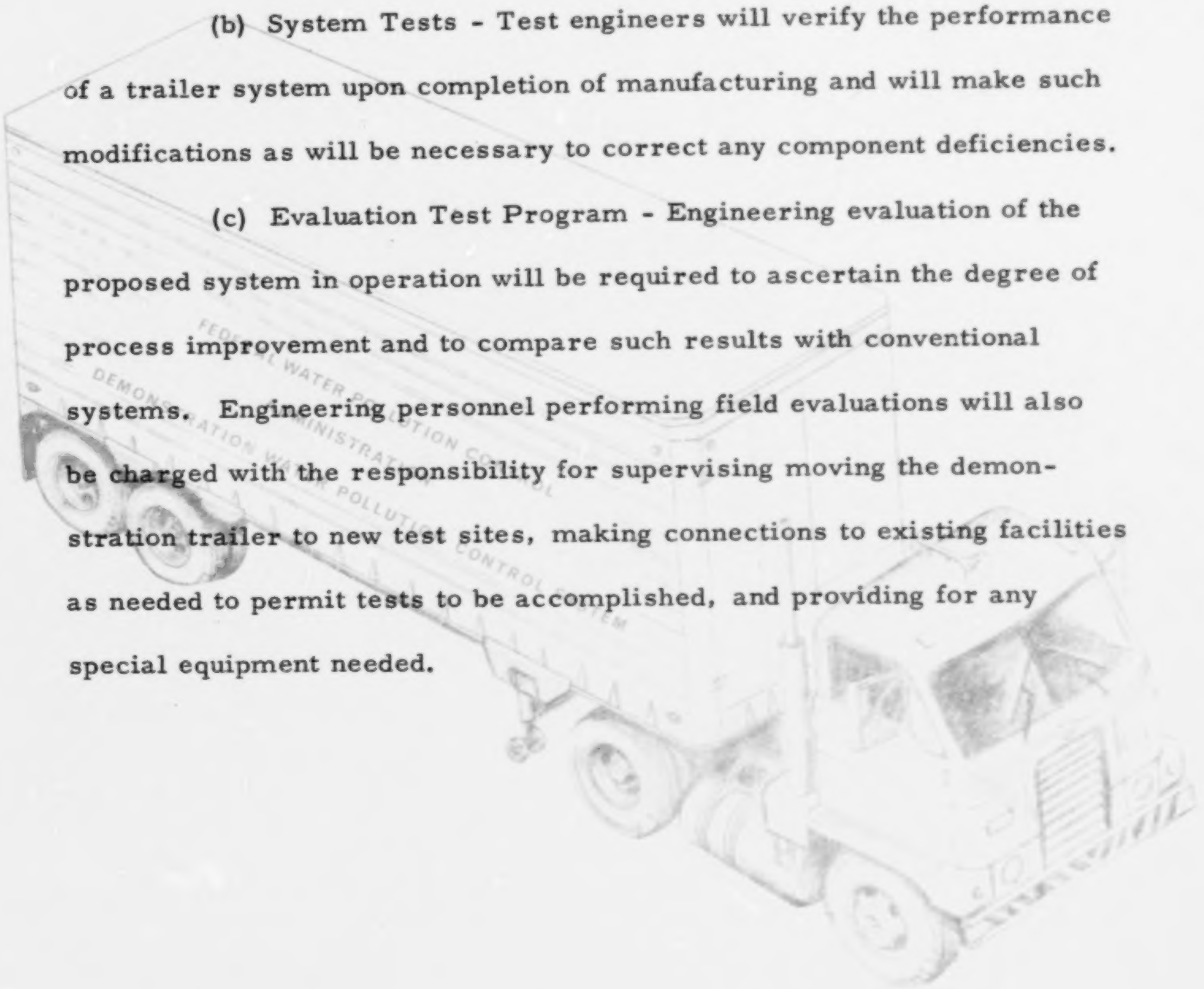
1. System Design - The filtration engineering effort required to accomplish the initial phase of a proposed program will involve the design of the basic ultrasonic filter module and its ancillary hydraulic equipment, including pumps, valves, and plumbing, primarily from the standpoint of minimizing head loss and of assuring complete operating reliability under the most rigorous expected conditions of use and mobility. Mechanical design effort will be needed to assist in modifying a standard trailer, provide access to equipment, install and verify the integrity of various components and evaluate operating safety and reliability. Electrical design effort will consider the ultrasonic generators, electrical

controls and power systems, and instrumentation.

2. (a) Manufacturing - Manufacturing effort will involve the building of forty ultrasonic filtration modules, eight ultrasonic generators plus one spare unit, the electronic control system, the hydraulic system and the mounting and assembly of all components in their correct positions.

(b) System Tests - Test engineers will verify the performance of a trailer system upon completion of manufacturing and will make such modifications as will be necessary to correct any component deficiencies.

(c) Evaluation Test Program - Engineering evaluation of the proposed system in operation will be required to ascertain the degree of process improvement and to compare such results with conventional systems. Engineering personnel performing field evaluations will also be charged with the responsibility for supervising moving the demonstration trailer to new test sites, making connections to existing facilities as needed to permit tests to be accomplished, and providing for any special equipment needed.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